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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF SAN LUIS FOREBAY DAM SPILLWAY--SAN LUIS UNIT--WEST SAN JOAQUIN DIVISION--CENTRAL VALLEY PROJECT, CALIFORNIA

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ABSTRACT

Model studies were conducted to develop the hydraulic design of the morning glory inlet and its approach, the vertical bend, the horizontal conduit, and the stilling basin. The diameter of the morning glory inlet and conduit was increased to accommodate the design flow at maximum reservoir elevation. A deflector, air vent, and guide vanes were installed in the vertical bend to direct the flow to the invert of the conduit and to reduce the oscillation of the flow through the conduit. The size of the stilling basin was increased and the end sill modified to eliminate the need for intermediate baffle piers.

DESCRIPTORS--*Spillways/ spillway crests/discharge coefficients/ hydraulic conduits/bends/hydraulic models/piezometers/*stilling basins/guide vanes/hydraulic jumps/hydraulic similitude

IDENTIFIERS--*Morning glory inlets/subatmospheric pressures/ conduit deflectors/baffle blocks

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Office of Chief Engineer	Report No. Hyd-517
Division of Research	Author: G. L. Beichley
Hydraulics Branch	Checked by: T. J. Rhone
Denver, Colorado	Reviewed by: W. E. Wagner
November 2, 1964	Submitted by: H. M. Martin

HYDRAULIC MODEL STUDIES OF SAN LUIS FOREBAY DAM SPILLWAY--SAN LUIS UNIT--WEST SAN JOAQUIN DIVISION CENTRAL VALLEY PROJECT, CALIFORNIA

PURPOSE

The studies were conducted to develop the hydraulic design of the spillway approach, the morning glory inlet, the vertical bend, the horizontal conduit, and the stilling basin.

CONCLUSIONS

1. Flow in the preliminary approach to the spillway inlet was satisfactory (Figure 14).

2. The diameter of the preliminary morning glory inlet structure and conduit was increased 11.9 percent to accommodate the design flow.

3. A deflector and air vent were installed on the crown side of the vertical bend (Figure 5) to steady the flow and provide a positive point from which the flow would spring from the crown of the conduit.

4. Guide vanes were placed on either side of the tunnel crown between the deflector and a point 42 feet downstream from the P.T. of the bend to reduce the flow oscillations through the conduit.

5. Pressures were near atmospheric or above in the modified inlet, vertical bend, and conduit.

6. A standard Type II stilling basin which was 10 feet longer than the preliminary basin was developed to eliminate the possibility of low pressures occurring on the floor baffles.

7. The height of the basin walls was increased 1 foot to contain the waves within the basin.

8. The modified stilling basin will adequately accomodate the design discharge with a minor amount of erosion in the downstream channel.

ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the Dams Branch and the Hydraulics Branch during the period December 1962 through June 1963. Photography was by Mr. W. M. Batts, Office Services Branch.

INTRODUCTION

San Luis Forebay Dam, as a part of the San Luis Unit of the West San Joaquin Division of the Central Valley Project, is located on San Luis Creek about 70 miles northwest of Fresno, California (Figure 1). The purpose of the unit is to store and utilize during the irrigation season wintertime water which otherwise would waste into the Pacific Ocean.

The dam (Figures 2 and 3) is an earthfill structure approximately 10, 000 feet long at the crest and about 70 feet high above the wasteway streambed. It will have a maximum reservoir area of approximately 2, 000 acres with a reservoir capacity of approximately 57, 500 acre-feet. Its principal feature is a pumping plant with a normal capacity of 4, 200 cfs (cubic feet per second).

The spillway, designed for a maximum discharge of 3, 250 cfs, is located in the left abutment of the dam (Figure 4). It has a morning glory type of inlet (Figure 5) that discharges into a vertical bend, which joins a nearly horizontal conduit whose invert at the P. T. of the bend is 60 feet below the crest. The conduit is 11 feet 9 inches in diameter and slopes downward on a grade of 0. 02137 for a distance of 327. 98 feet to a chute. The chute curves downward and discharges the flow into a stilling basin (Figure 6). The basin floor is 12 feet lower than the invert of the conduit exit portal. The stilling basin discharges the flow into an excavated trapezoidal channel.

Dimensions of the hydraulic features are listed in Table 1 for both English and metric units.

THE MODEL

Scope

The model (Figure 7), as originally constructed, was a 1:21.91 scale reproduction of the spillway inlet, the vertical bend, the horizontal conduit, and the stilling basin. A portion of the reservoir surrounding the inlet and a short length of the wasteway from the stilling basin were included in the model. During the course of the model study the inlet, vertical bend, and horizontal conduit were increased in size to meet certain design requirements. The model dimensions of these parts were not changed; therefore, this portion of the model study was based on 1:24.52 scale ratio.

Reservoir

The reservoir was contained in a 16- by 16-foot head box (Figure 7) which allowed reproduction of the reservoir for approximately 150 feet to the right and left of the inlet and approximately 350 feet upstream from the face of the dam. The upstream face of the dam and the excavated approach area including the canal from the pumping plant were molded of concrete mortar placed on metal lath which had been nailed over wooden templates shaped to the surface contours. A 6-inch rock baffle was installed along the reservoir side of the approach area to smooth the water surface and distribute the inflow.

The reservoir water surface elevation was measured by means of a hook gage mounted within a well attached to the side of the box and connected to a piezometer tap located in the floor of the canal to the pumping plant. At this location the velocity of approach was negligible.

Morning Glory Inlet

The inlet was molded of concrete screeded to sheet metal templates. Piezometers were installed in the spillway crest and consisted of 1/16-inch-inside-diameter brass tubes soldered at right angles to the profile shape and filed flush.

Vertical Bend and Conduit

The vertical bend and conduit were constructed of transparent plastic. The conduit was made from 5-3/4-inch-inside-diameter extruded pipe. This governed the scale of the model. Plastic piezometers having a 1/16-inch inside diameter were installed in critical areas.

THE INVESTIGATION

The investigation was concerned with flow conditions in the inlet, vertical bend, horizontal conduit, and stilling basin for flows up to and including the designed maximum discharge of 3,250 cfs (originally 3,600 cfs).

Preliminary Inlet and Vertical Bend

Description.--The morning glory inlet was located in an excavated level area near the left abutment of the dam (Figure 3). Its crest was 10 feet above the surrounding level bench. An excavated canal from the outlet structure of the Forebay Pumping Plant crossed through the bench to the left of the inlet. The preliminary inlet and vertical bend (Figure 8) did not include a deflector, air vent, or guide vanes. It was anticipated that these would be required but that they should be developed by means of the model study.

Flow characteristics.--The flow approached the inlet in a very smooth and tranquil manner for all discharges. However, the flow currents approaching the inlet from the left and right opposed each other along a plane approximately 90° to the left of the spillway centerline. This caused a fin of water to form deep in the throat of the inlet (Figure 9A). This fin of water was larger than the normal wrinkling of the water surface that formed around the remainder of the throat circumference. Traveling waves were imposed upon the wrinkled water surface when wind waves were simulated in the model reservoir.

For a flow of 3,600 cfs the throat filled and a boil formed in the inlet (Figure 9B). The elevation of the boil fluctuated, but the boil did not rise to a height to submerge the crest.

In the vertical bend (Figure 10) the flow currents spiraled slightly and thin sheets of water crossed over the crown. As a result, the flow oscillated from side to side in the horizontal conduit. The oscillating flow was more pronounced when waves were generated in the reservoir. For a flow of 3,600 cfs the flow through the vertical bend and horizontal conduit was unsteady; i.e., portions of the conduit momentarily filled and then became vented by air from the inlet. The choking of the inlet throat hindered the normal free flow of air through the inlet and conduit. These conditions indicated that a deflector with air vent was needed to provide a positive point from which the flow would spring from the crown of the conduit, and that guide vanes were needed to reduce the oscillations and maintain a more uniform water surface in the conduit.

Calibration.--Calibration of the preliminary design, Figure 11, showed that the original design flow of 3,600 cfs was discharged at 0.37 foot above maximum reservoir elevation 228.00 and that only 3,000 cfs would be discharged at the maximum reservoir elevation. These results indicated that the crest length and the inlet diameter should be increased approximately 20 percent.

Submergence.--The morning glory inlet submerged at approximately reservoir elevation 228.75 with a discharge of about 4,200 cfs. At submergence the discharge coefficient, Figure 11, was 3.57 as compared to 3.50 at reservoir elevation 228.00. After submergence the coefficient dropped rapidly to about 1.10 and the reservoir rose abruptly to approximately elevation 233.00 before the conduit filled completely. After the conduit filled the flow was steady, and the discharge increased at a faster rate per unit increase in reservoir elevation.

Pressures.--Pressures (Figure 12) were subatmospheric in the lower region of the crest profile and along the crown of the vertical bend. Water manometer pressures on the crown of the vertical bend fluctuated between approximately 15 and 20 feet of water below atmospheric at a discharge of 3,600 cfs. The fluctuation was due to the unsteady flow condition previously described. As the flow approached a submerged condition, the degree of pressure fluctuation diminished. At 4,200 cfs the crest became submerged and the pressures were steady.

For a discharge of 1,800 cfs the pressures in the lower region of the inlet and in the vertical bend were steady and reached a minimum of about 5 feet of water below atmospheric (Figure 12). Pressures on the upper portions of the inlet profile were slightly above atmospheric. These pressures indicated that the inlet profile was a little too flat in the upper region and curved downward a little too rapidly in the lower region for uniform atmospheric pressure to exist on the complete profile. Both Creager, Justin, and Hinds1/ and Wagner2/ indicate that the theoretical profile of the crest should curve more steeply than the design profile in the upper region and less steeply in the lower region. Due to the low head-to-crest radius ratio (approximately 0.11), the theoretical profile of the crest was not tangent to the P.C. of the vertical bend. Therefore, it was necessary to deviate

1/Creager, Justin, and Hinds, "Engineering of Dams Volume I, General Design."
2/Paper No. 2802 ASCE Transactions, Volume 121, 1956, page 311, Morning-glory Shaft Spillways Symposium, "Determination of Pressure-controlled Profiles," by William E. Wagner, M ASCE.

from the theoretical profile in order to bring the design profile tangent at the P. C. of the vertical bend. The elevation of the P. C. of the vertical bend was fixed within narrow limits by the elevation of the near horizontal conduit and stilling basin.

Inlet and Vertical Bend Modifications

Initially, it was planned to raise the allowable maximum reservoir elevation 0.37 foot to elevation 228.37 in order to discharge the anticipated flow of 3,600 cfs. It was thought that only modifications to the vertical bend and conduit might be required to insure smooth, steady flow through the conduit without the conduit flowing more than 0.8 full and without the presence of severe subatmospheric pressures. Several schemes were tested.

Three-, six-, and nine-inch deflectors installed at the P. C. on the crown side of the vertical bend were found to be infeasible because they constricted the flow area and limited the discharge to less than 3,600 cfs at reservoir elevation 228.37 (Figure 11). The 9-inch deflector insured steady, free-surface flow through the conduit but limited the maximum flow to approximately 3,100 cfs at reservoir elevation 228.37. The 3- and 6-inch deflectors, in addition to limiting the maximum flow, did not insure free-surface flow.

The vertical bend was lowered 2 feet by installing a 2-foot tangent length of conduit between the morning glory throat and the P. C. of the bend. This increased the flow only a negligible amount.

Next, a deflector was installed tangent to the crown of the vertical bend and ended at the P. T. where it projected downward 12 inches toward the center of the conduit. An air vent was placed at the downstream end of the deflector. With this deflector the maximum free flow over the crest was 3,600 cfs at reservoir elevation 228.37 (Figure 11). However, this deflector was not large enough to insure steady, free-surface flow through the conduit for the maximum anticipated flow of 3,600 cfs and the subatmospheric pressures on the crown of the bend were not reduced. A 24-inch deflector at the P. T. of the crown of the bend caused the throat of the inlet and vertical bend to fill and reduced the flow at maximum reservoir elevation 228.37 to approximately 3,350 cfs (Figure 11). The discharge was increased to 3,400 cfs by placing a 2-foot tangent length of vertical conduit between the throat of the morning glory and the P. C. of the vertical bend (Figure 11). Since the vertical bend flowed full, the subatmospheric pressures that had been noted on the crown of the bend upstream of the deflector were reduced. However, at about 3,200 cfs the pressures fluctuated from about 3 feet of water below atmospheric to about 12 feet above. For discharges above 3,200 cfs, the pressures were fairly steady at about 8 feet of water below atmospheric.

At this stage of the investigation, the design flood was rerouted through the reservoir and it was determined that the required maximum spillway discharge could possibly be reduced to 3,210 cfs at reservoir elevation 228.26. This requirement could be met easily with a 24-inch deflector at the P.T. of the bend but not with a 9-inch deflector at the P.C. (Figure 11). A smaller deflector at the P.C. met the discharge requirements but was too small to adequately deflect the flow from the crown of the conduit.

Additional capacity and pressure tests of the inlet were made with the vertical bend removed. This arrangement simulated the inlet discharging into a fully vented vertical bend having a diameter larger than the inlet throat diameter. With this arrangement, the discharge at the revised maximum reservoir elevation 228.26 was approximately 3,450 cfs (Figure 11), which was 240 cfs more than the revised requirement of 3,210 cfs and 150 cfs less than the originally anticipated flow of 3,600 cfs. For 3,600 cfs pressures on the crest profile were above atmospheric but fluctuated considerably (Figure 12).

This design was not considered further since extensive revisions to the vertical bend and conduit would be required to develop good flow conditions. Instead, it was decided to increase the size of the structure to increase the capacity to 3,600 cfs at reservoir elevation 228.26.

Recommended Inlet and Vertical Bend

Description.--The diameters of the inlet, vertical bend, and conduit were increased 11.9 percent to attain a discharge of 3,600 cfs at reservoir elevation 228.26. The outside diameter of the inlet was increased from 54 to 60.5 feet and the conduit diameter from 10.5 to 11.75 feet (Figures 4 and 5). The crest elevation remained the same but the P.T. of the invert of the vertical bend was lowered 6.4 feet to elevation 165.00, which changed the slope of the conduit. A 27-inch deflector was extended vertically downward from the P.C. of the crown of the vertical bend. An air vent was installed below the deflector. Guide vanes were placed along the crown of the conduit and extended from the downstream corners of the deflector, through the vertical bend, and for a distance of 42.48 feet into the conduit. The 2-foot-wide undersurfaces of the vanes were tilted downward 4 inches to intercept and turn the spinning sheets of water downward toward the center of the conduit. Intake to the air vent was through a pier located on the crown side of the circular crest.

Rather than reconstruct the model, the model scale was increased 11.9 percent from 1:21.91 to 1:24.52 for completion of the inlet, vertical bend, and conduit tests. However, the slope of the tunnel was revised from 0.035 to 0.02137 since the station and elevation of the exit portal was not revised in accordance with the 11.9 percent.

Calibration. --The discharge capacity of the revised inlet was 3,610 cfs at reservoir elevation 228.26 (Figure 13). At this stage of the study, it was learned that a much larger quantity of material would be excavated from the reservoir area for the construction of San Luis Dam than originally anticipated. This excavation sufficiently increased the storage capacity of the reservoir to reduce the required design discharge to 3,250 cfs at reservoir elevation 228.00. Calibration of the model spillway showed the capacity to slightly exceed this requirement (Figure 13). The discharge coefficient in the equation $Q = CLH^{3/2}$ was approximately 3.45 at 3,250 cfs (Figure 13).

Flow characteristics. --Flow conditions in the approach area and in the spillway inlet were excellent. However, flow currents approaching the inlet merged along a plane approximately 90° to the left of the spillway centerline and caused a fin of water to form deep in the throat of the morning glory inlet (Figures 14 and 15). The fin was in addition to the normal wrinkling of the water surface.

The throat did not choke up until the discharge exceeded 3,250 cfs (Figures 13, 14, and 15). Even with 2-foot wind waves imposed upon the reservoir water surface, the throat of the inlet did not choke up at a discharge of 3,250 cfs (Figure 15).

Flow in the vertical bend and conduit (Figures 16 and 17) was steady. The air demand through the vent was not excessive since the air vent could be closed without affecting the steady flow condition. The crown of the vertical bend and horizontal conduit was free from oscillating flow and spinning sheets of water at all discharges. However, 2-foot-high wind waves on the reservoir water surface caused some spinning of the flow and some oscillation of the water surface through the conduit. These oscillations were damped out by the two 2-foot-wide guide vanes (Figures 4 and 5) along the crown of the conduit downstream from the face of the deflector.

Pressures. --Pressures in the inlet and conduit (Figures 18 and 19) were satisfactory. No severe subatmospheric pressures were detected. Pressures on the guide vanes were not measured since a similar installation in the vertical bend of the San Luis Dam spillway showed no severe subatmospheric pressures to exist. 3/

3/ Bureau of Reclamation, Hydraulic Branch Report No. Hyd-515 "Hydraulic Model Studies of San Luis Dam Spillway, Central Valley Project, California," by G. L. Beichley.

Flow depths.--Flow depths were measured in the conduit for comparison with pressures. The pressures along the invert of the horizontal conduit were a little greater than indicated by the flow depths (Figure 19).

Stilling Basin Test Procedures

The 1:21.91 scale model was used to develop the stilling basin. For most tests, a 12-inch (prototype) deflector was installed at the beginning of the vertical bend to control the flow through the inlet, and raise the reservoir enough to increase the velocity, V_1, at the chute blocks from approximately 52 to 60 feet per second. For this condition the entrance depth, D_1, was 2.4 feet and the Froude number was 6.82. This additional head compensated for model conduit roughness which offered more frictional resistance to the flow than designed for in the prototype.

The model roughness coefficient, n, in the Manning's equation, is estimated to be between 0.008 and 0.009, which represents a prototype coefficient of between 0.013 and 0.015. To be on the side of safety, the stilling basin is designed to maintain a hydraulic jump for an entrance velocity based on a prototype roughness coefficient of 0.008. This would produce a velocity of approximately 65 feet per second at the chute blocks. However, the actual prototype roughness coefficient is more likely to be closer to 0.013, which would produce a velocity of about 57 feet per second.

For a few tests, the deflector size was increased sufficiently to raise the reservoir water surface to the top of the model head box, which increased the average velocity to 63.7 feet per second. For this condition, D_1 was 2.26 feet and the Froude number was 7.48. Some of the tests in the preliminary basin were made without choking the inlet in which case V_1 was 52 feet per second, D_1 was 2.78 feet, and F was 5.5; other tests were made by choking the inlet with a 9-inch deflector in which case V_1 was 57.8 feet per second, D_1 was 2.5 feet, and F was 6.44 feet.

Preliminary Transition and Stilling Basin

Description.--The preliminary basin (Figure 8) contained floor baffles and a solid end sill. The floor baffles were at a distance of 0.8 D_2 (18 feet) downstream from the chute blocks. The anticipated tailwater for the design flow was estimated to be between elevations 168.00 and 170.00.

Flow characteristics.--At the exit portal flow conditions were satisfactory in both the conduit transition section and the chute trajectory. The flow distribution across the width of the chute trajectory at the entrance to the stilling basin was also very good.

The stilling basin dissipated the energy very well, even at an entrance velocity of 63.7 feet per second and minimum tailwater elevation 168.00 (Figure 20). The tailwater could be lowered 5.5 feet to elevation 162.5 before the chute blocks were uncovered and even then the hydraulic jump was effective. The water surface in the downstream portion of the basin was relatively smooth.

Erosion.--Channel erosion downstream from the basin was minor (Figure 20). At the two downstream corners of the basin the sand bed in the model was eroded from end sill elevation 148.25 to elevations 146 and 145. It was anticipated that the 3-foot riprap called for in the specifications would provide ample protection to the structure.

Pressures.--Pressures in the transition, chute trajectory, and stilling basin were satisfactory for an entrance velocity, V_1, of 52 feet per second with tailwater elevation 168.00 (Figure 21). For this tailwater elevation, the baffle block pressures fluctuated to as much as 5 feet of water below atmospheric. As the tailwater was lowered to elevation 164.00, the pressures on the baffles were progressively reduced to a minimum of 22 feet below atmospheric at piezometer 75 (Figure 21).

Pressures for the higher test velocities were not recorded; however, increasing the entrance velocity lowered the pressures on both chute blocks and floor baffles. Therefore, it seemed desirable to develop a basin without use of the baffle blocks if economically feasible.

First Modification to the Stilling Basin

Flow characteristics.--With the baffle blocks removed, the basin appeared to be sufficiently long and deep to contain the hydraulic jump for the anticipated maximum flow of 3,600 cfs discharging at a velocity of 57.8 feet per second (Figure 22). However, surges within the jump were quite large and extended beyond the end of the basin.

Average water surfaces profiles for the design flow entering the basin at 52 feet per second with the tailwater at elevations 170.00 and 168.00 are shown in Figure 23. The tailwater could be lowered to elevation 164.00 before the chute blocks were completely exposed and to elevation 162.50 before the jump was on the verge of sweeping out of the basin.

Erosion.--Erosion was minor but slightly greater than in the preliminary design. Compare Figures 20 and 22.

Second Modification to the Transition and Stilling Basin

Description.--The recommended changes in the conduit diameter and slope resulted in a longer portal transition, flatter chute trajectory from the conduit portal to the basin floor, and a slight decrease in the angle of flare of the chute trajectory walls. In addition, the design flow tailwater was increased from elevation 168.00 to elevation 170.00, and the stilling basin floor was raised 1.5 feet to elevation 146.50. The length of the basin was not changed.

The changes in conduit transition and chute trajectory were not made in the model since no hydraulic problems in either could be anticipated based on the preliminary design tests. To reflect the change in basin floor elevation without physically modifying the basin in the model, the channel bed and the tailwater were lowered 1.5 feet.

Flow characteristics.--For the design flow of 3,600 cfs with an average entrance velocity of 52 feet per second, the modified basin performed quite well. The water surface in the basin at tailwater elevation 170.00 was approximately the same as shown for tailwater elevation 168.00 in the first modification (Figure 23).

When the entrance velocity was increased to 63.7 feet per second, the hydraulic jump moved downstream and created a rough water surface downstream from the basin (Figure 24). The toe of the jump was 20 feet upstream from the downstream end of chute blocks with tailwater elevation 170.00, and 5 feet upstream with tailwater elevation 168.00. At tailwater elevation 166.00 the jump was practically swept out of the basin with the toe of the jump near the end sill. By reducing the velocity to 60 feet per second and maintaining tailwater elevation 166.00, the toe of the jump moved upstream to within about 25 feet of the chute blocks; however, the jump was still considered to be nearly swept out.

Erosion.--The channel bed was eroded at the downstream corners of the basin (Figure 24) about the same as observed with the previous basins. However, the eddies washed in much more of the channel banks and deposited a larger mound of material in the center of the channel.

Pressures.--Pressures in the modified basin were satisfactory with an entrance velocity of 60 feet per second for design flow 3,600 cfs at tailwater elevation 170.00 (Figures 25 and 26). The lowest water manometer pressure was at Piezometer 67 on the side of the chute block, and fluctuated to 6 feet below atmospheric at tailwater elevation 170.00. For this test condition, pressure transducers indicated an average minimum instantaneous pressure of 15 feet of water below atmospheric and an average mean pressure of 3 feet of water above atmospheric. By lowering the tailwater below elevation 170.00 or increasing the entrance velocity, still lower subatmospheric pressures were observed (Figures 26 and 27). Increasing the entrance velocity to 63.7 feet per second lowered the minimum water manometer pressure to 13 feet of water below atmospheric for tailwater elevation 170.00 (Figure 27).

Pressure transducers were attached to the piezometers in the two most critical pressure areas on the chute blocks and to some of the wall piezometers to measure dynamic pressure fluctuations. These pressures, shown in tabular form in Figures 25 and 26, were measured to determine the severity of the instantaneous subatmospheric pressures in these areas and to aid in the design of the basin walls. It was decided to streamline the chute blocks as a precautionary measure.

Recommended Stilling Basin

Description.--The recommended basin (Figure 6) was 80 feet long with its floor at elevation 146.00 and its training walls extended to elevation 176.00. This basin was 10 feet longer and one-half foot deeper than the second modified basin and the walls were 1 foot higher. To follow established design practices for a Type II basin, the solid end sill of the preliminary basin was replaced with a dentated end sill. The top edges of the chute blocks were streamlined with a 10-inch radius. The design flow was reduced to 3,250 cfs and the design tailwater was established at elevation 169.5 prior to installation of this basin.

Flow characteristics.--The basin performance was excellent at all flows up to and including the maximum discharge of 3,250 cfs with the entrance velocity at 63.7 feet per second and tailwater elevation 169.5 (Figure 28). Most of the surface turbulence created by the hydraulic jump occurred within the basin rather than in the downstream channel, which was the reason for extending the basin walls to elevation 176.00. The dentated end sill aided slightly in smoothing the water surface beyond the end of the basin.

The chute blocks were uncovered when the tailwater was lowered to elevation 167.00, and the hydraulic jump was on the verge of sweeping out of the basin when the tailwater was lowered to elevation 166.00.

The performance of this basin was an improvement over that of the second modified basin and was believed to provide sufficient safety factor against sweepout. The safety factor and the performance were improved further when the entrance velocity was reduced to that computed for a conduit roughness coefficient of $n = 0.013$.

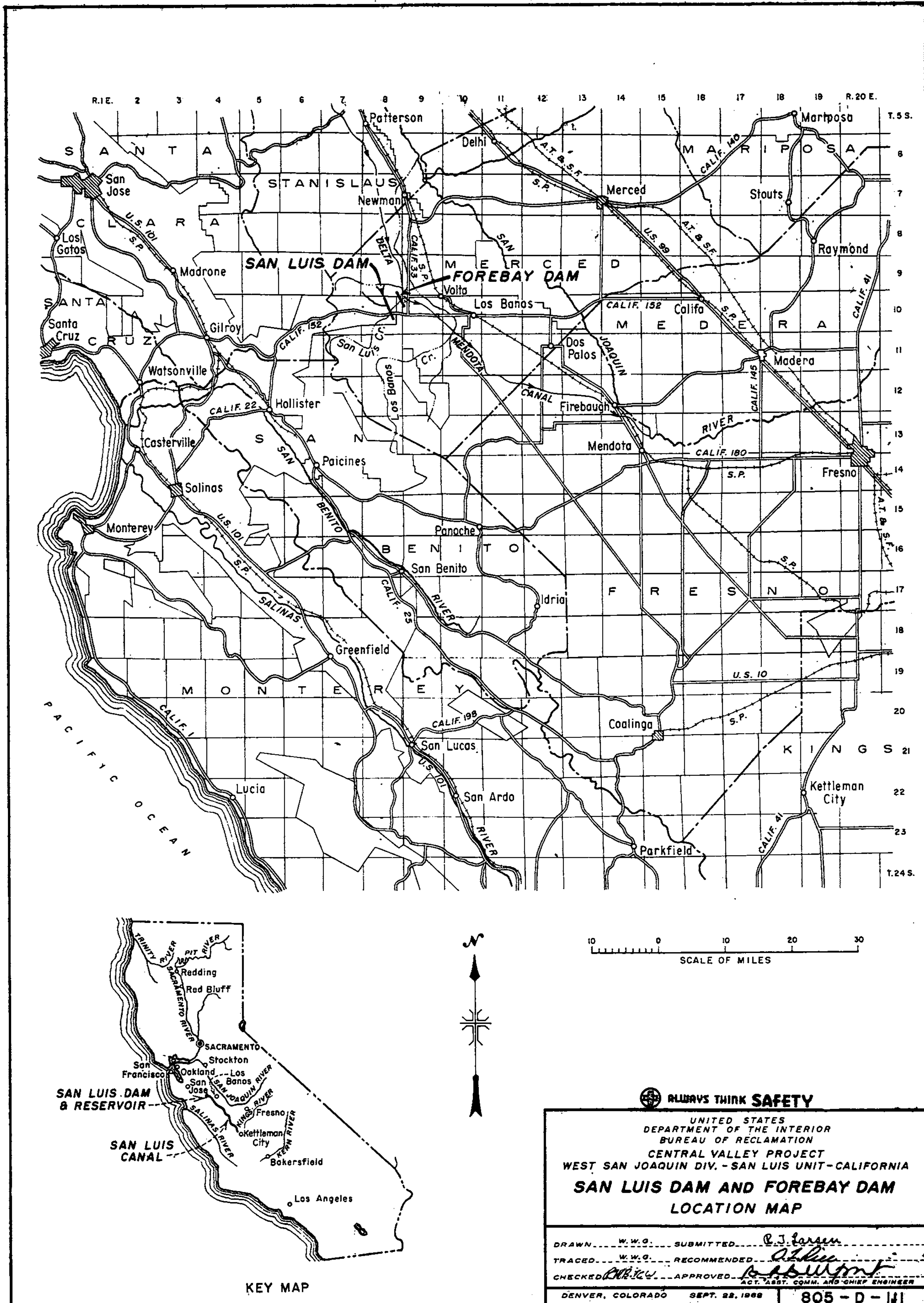
Erosion. --Erosion of the channel was about the same as in the preceding designs. At the downstream corners of the model basin the sand channel was eroded from elevation 3146 to elevation 3145.5. It was anticipated that 3-foot riprap called for in the specifications would provide ample protection to the structure.

Pressures. --Pressures in the recommended basin were not measured since the pressures can be assumed to be slightly higher than those observed in the second modification due to the 0.5-foot lower floor elevation (Figure 25). Pressures along the sides of the chute blocks (Figures 26 and 27) for the second modified basin will be increased by the streamlining of the chute blocks in the recommended basin.

Table 1

DIMENSIONS OF HYDRAULIC FEATURES

Feature	English units	Metric units
Height of dam	70 feet	21.34 meters
Length of dam at crest	10,000 feet	3,048 meters
Reservoir area	2,000 acres	8.09 square kilometers
Reservoir capacity	57,500 acre-feet	7.09×10^7 cubic meters
Spillway design capacity	3,250 cfs	92.03 cubic meters per second
Head on crest at design capacity	3 feet	0.91 meters
Morning glory inlet diameter	60.5 feet	18.44 meters
Vertical bend center-line radius	16.79 feet	5.12 meters
Spillway conduit diameter	11.75 feet	3.58 meters
Drop from crest to conduit invert	60 feet	18.29 meters
Conduit length	327.98 feet	99.97 meters
Basin length (portal to end sill)	160 feet	48.77 meters
Drop from crest to basin floor	79 feet	24.08 meters


SAN LUIS DAM
FOREBAY DAM
Patterson
Delhi
Merced
Mariposa
Stouts
Raymond
San Jose
Newman
Los Gatos
Madrone
Volta
Los Banos
Califa
Santa Cruz
Gilroy
Dos Palos
Madera
Watsonville
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Firebaugh
Castroville
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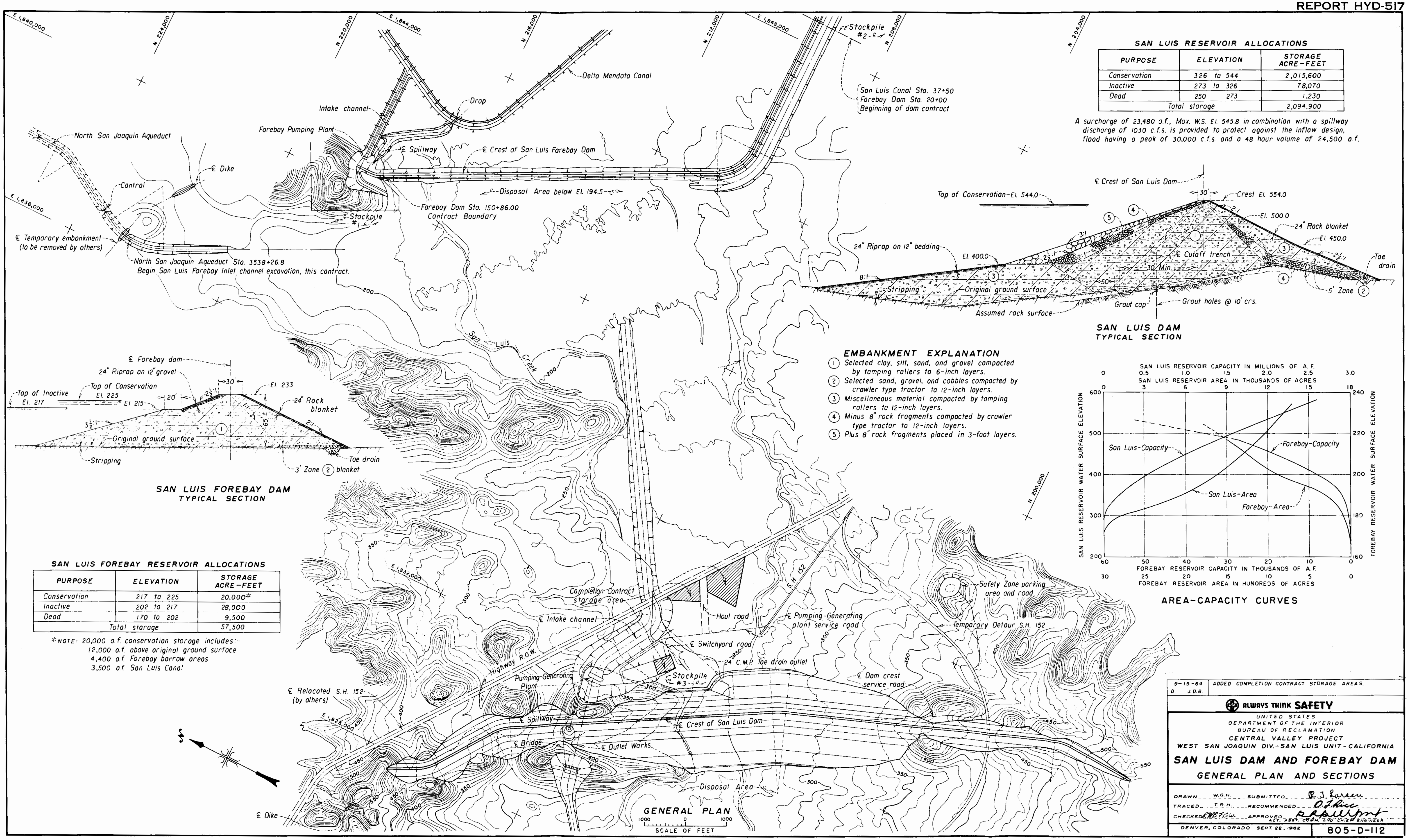
SAN LUIS DAM AND FOREBAY DAM
LOCATION MAP
DRAWN W.W.G. SUBMITTED
TRACED W.W.G. RECOMMENDED
CHECKED APPROVED
ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO SEPT. 22, 1960
805-D-111

FIGURE 2
REPORT HYD-517



SAN LUIS RESERVOIR ALLOCATIONS

PURPOSE	ELEVATION	STORAGE ACRE-FEET
Conservation	326 to 544	2,015,600
Inactive	273 to 326	78,070
Dead	250 273	1,230
Total storage		2,094,900

A surcharge of 23,480 a.f., Max. W.S. El. 545.8 in combination with a spillway discharge of 1030 c.f.s. is provided to protect against the inflow design, flood having a peak of 30,000 c.f.s. and a 48 hour volume of 24,500 a.f.

SAN LUIS FOREBAY RESERVOIR ALLOCATIONS

PURPOSE	ELEVATION	STORAGE ACRE-FEET
Conservation	217 to 225	20,000*
Inactive	202 to 217	28,000
Dead	170 to 202	9,500
Total storage		57,500

*NOTE: 20,000 a.f. conservation storage includes:-
12,000 a.f. above original ground surface
4,400 a.f. Forebay barrow areas
3,500 a.f. San Luis Canal

9-15-64 D. J.D.B. ADDED COMPLETION CONTRACT STORAGE AREAS.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV.-SAN LUIS UNIT-CALIFORNIA

SAN LUIS DAM AND FOREBAY DAM
GENERAL PLAN AND SECTIONS

DRAWN W.G.H. SUBMITTED R.J. Larsen
TRACED T.R.H. RECOMMENDED O.L. Rice
CHECKED APPROVED ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO SEPT. 28, 1962 805-D-112

FIGURE 3
REPORT HYD-517

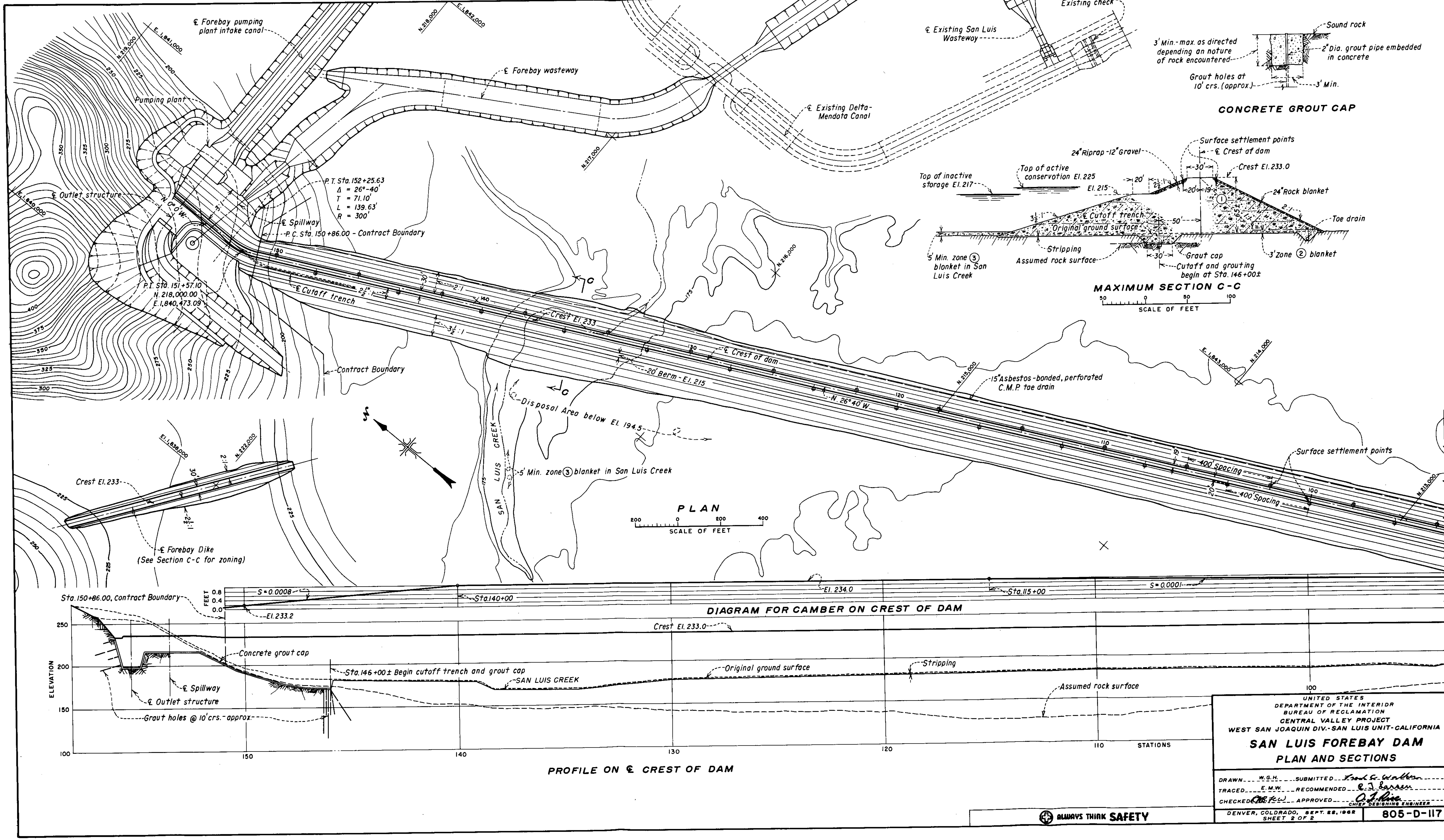
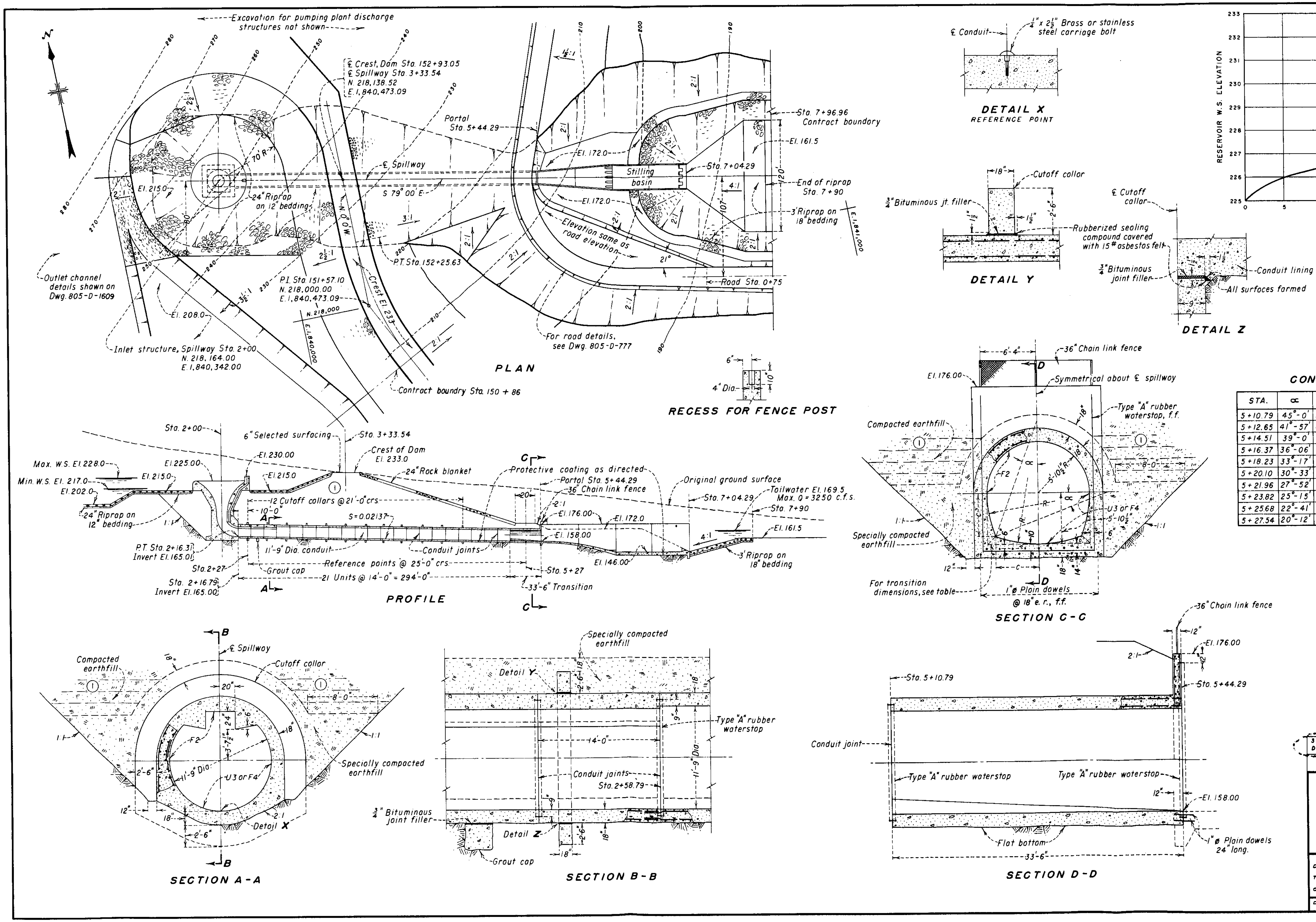
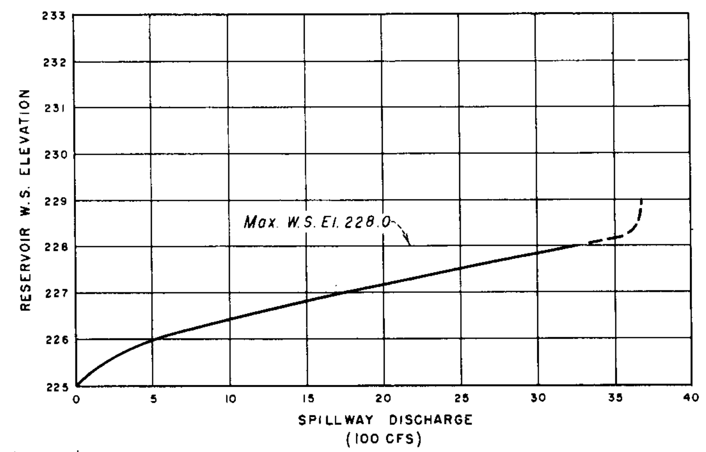


FIGURE 4
REPORT HYD-517





CONDUIT TRANSITION TABLE

STA.	∝	R	C
5+10.79	45°-0'	5'-10 1/2"	4'-1 7/8"
5+12.65	41°-57'	6'-4 1/4"	4'-2 15/16"
5+14.51	39°-0'	6'-10 5/8"	4'-4"
5+16.37	36°-06'	7'-6 3/16"	4'-5 1/8"
5+18.23	33°-17'	8'-2 7/8"	4'-6 1/4"
5+20.10	30°-33'	9'-1"	4'-7 3/8"
5+21.96	27°-52'	10'-0 7/8"	4'-8 1/2"
5+23.82	25°-15'	11'-3 1/16"	4'-9 5/8"
5+25.68	22°-41'	12'-8 1/4"	4'-10 3/4"
5+27.54	20°-12'	14'-5 3/8"	4'-11 7/8"

STA.	∝	R	C
5+29.40	17°-45'	16'-8"	5'-1"
5+31.26	15°-22'	19'-6 3/8"	5'-2 1/8"
5+33.12	13°-02'	23'-4 1/2"	5'-3 1/4"
5+34.98	10°-45'	28'-9 7/16"	5'-4 7/16"
5+36.85	8°-31'	36'-11 5/16"	5'-5 5/8"
5+38.71	6°-19'	50'-6 3/4"	5'-6 13/16"
5+40.57	4°-10'	77'-10 9/16"	5'-8"
5+42.43	2°-04'	159'-11 1/4"	5'-9 1/4"
5+44.29	0°	∞	5'-10 1/2"

NOTES

For general concrete outline notes, see Dwg 40-D-5530.

3-6-64 D G.U.T.	REVISED RIPRAP PATTERN AT INLET. CORRECTED BEDDING DIMENSION.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV-SAN LUIS UNIT-CALIFORNIA

SAN LUIS FOREBAY DAM

SPILLWAY
PLAN, PROFILE AND SECTIONS

DRAWN G.F.K. SUBMITTED R.H. Whinnerah
TRACED G.L.S. RECOMMENDED R.J. Larsen
CHECKED R.A.K. M.G.J. APPROVED A.T. Rice CHIEF DESIGNING ENGINEER
DENVER, COLORADO, AUGUST 13, 1963 | 805-D-1598

FIGURE 5
REPORT HYD-517

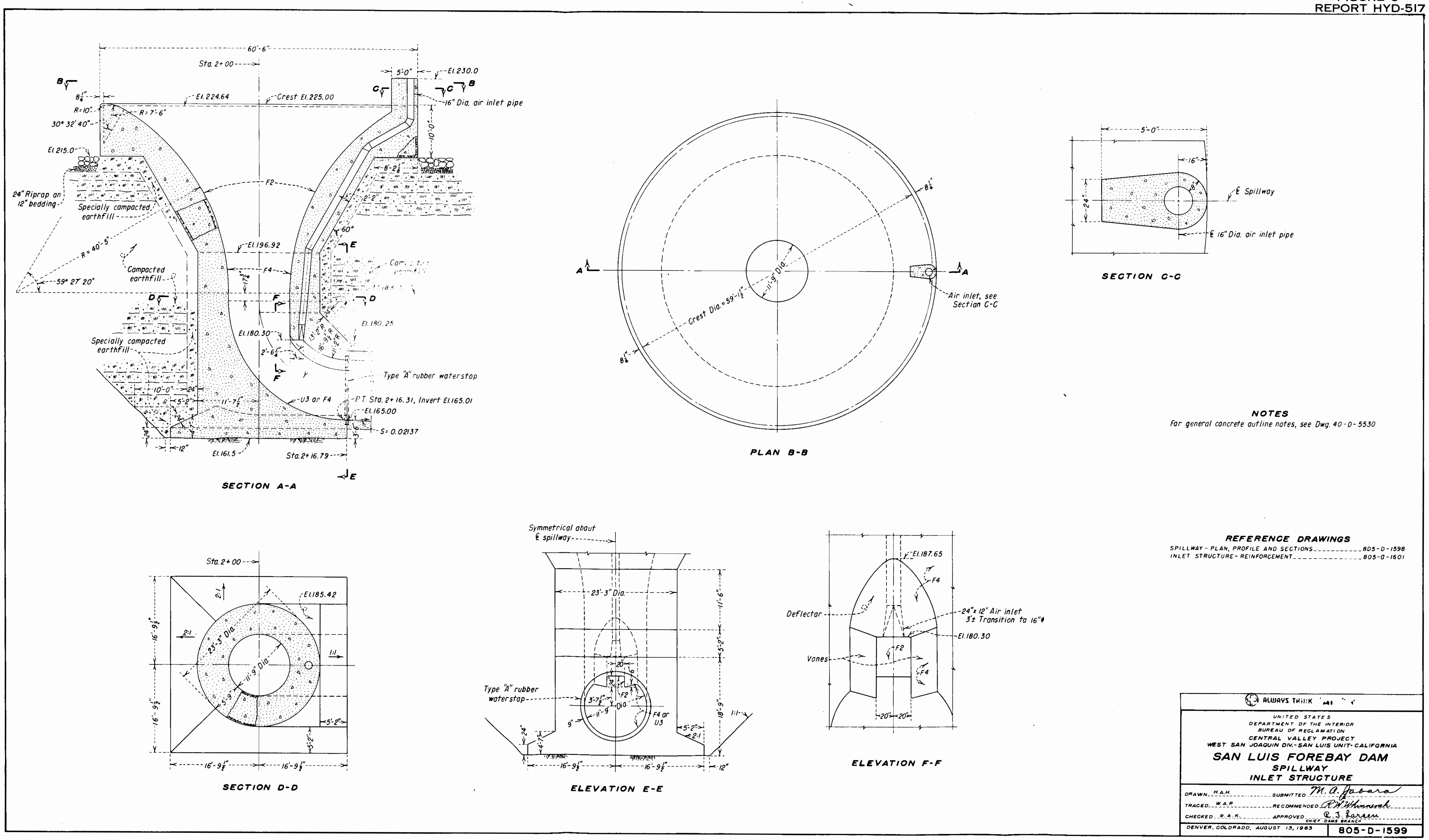
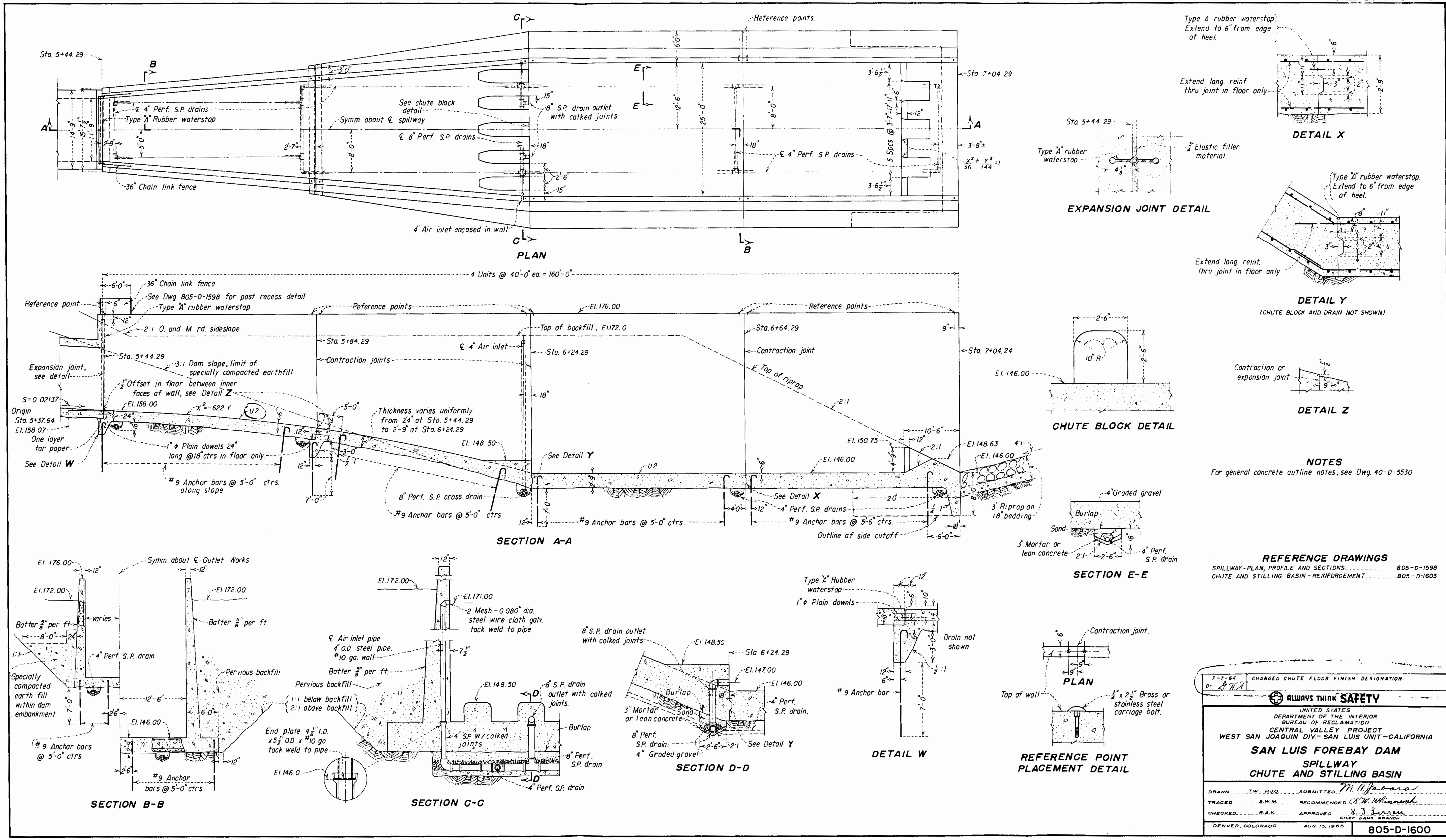
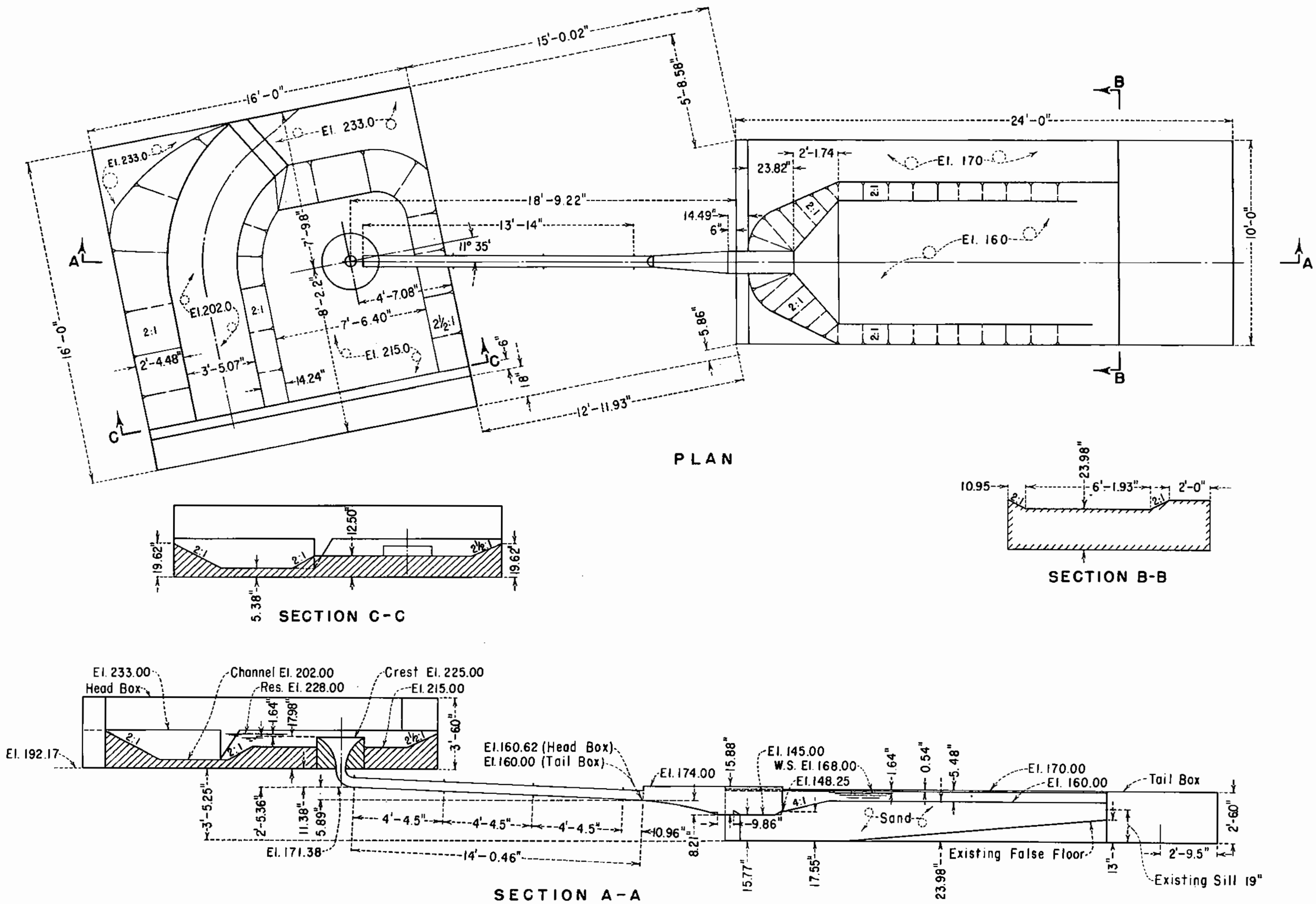


FIGURE 6
REPORT HYD-517

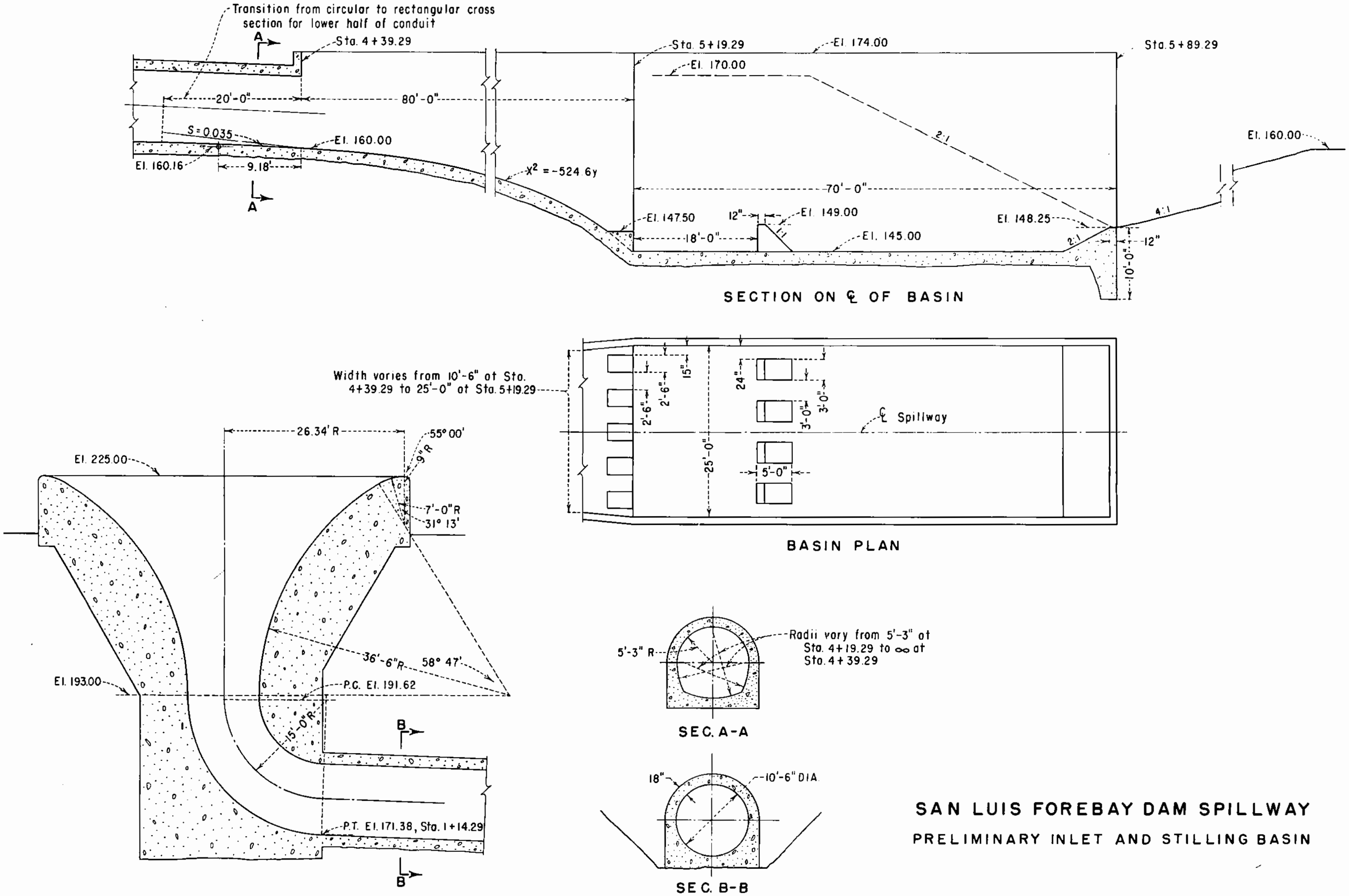




SAN LUIS FOREBAY DAM SPILLWAY

1:21.91 SCALE MODEL

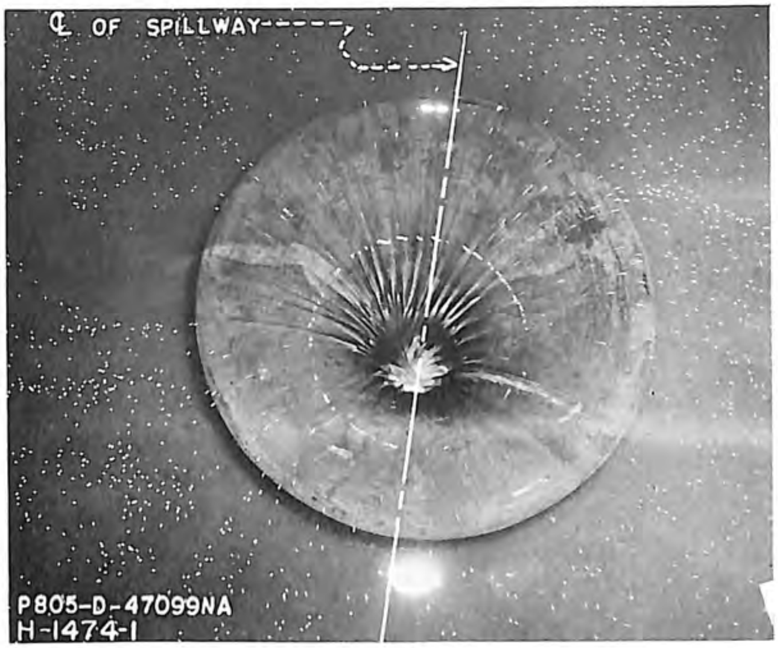
FIGURE 7
REPORT HYD-517



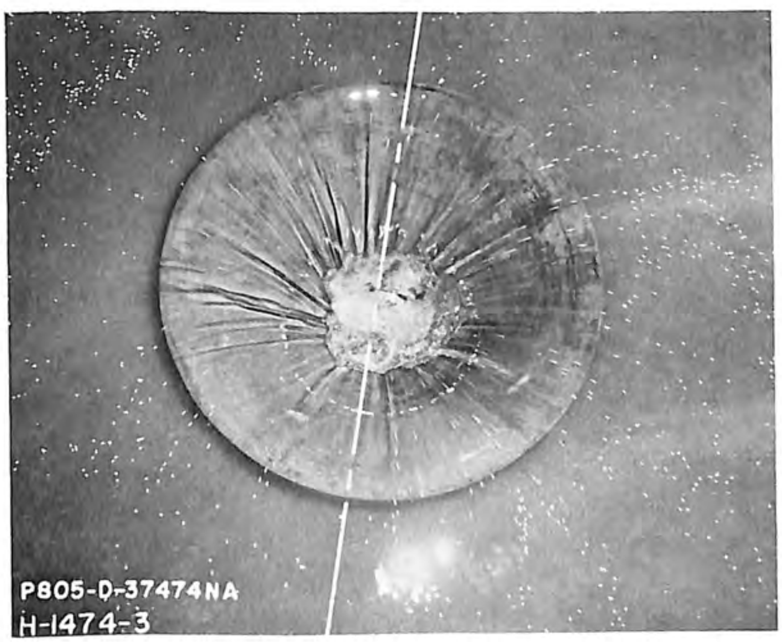
SAN LUIS FOREBAY DAM SPILLWAY

PRELIMINARY INLET AND STILLING BASIN

FIGURE 8
REPORT HYD-517



A. 1,800 cfs

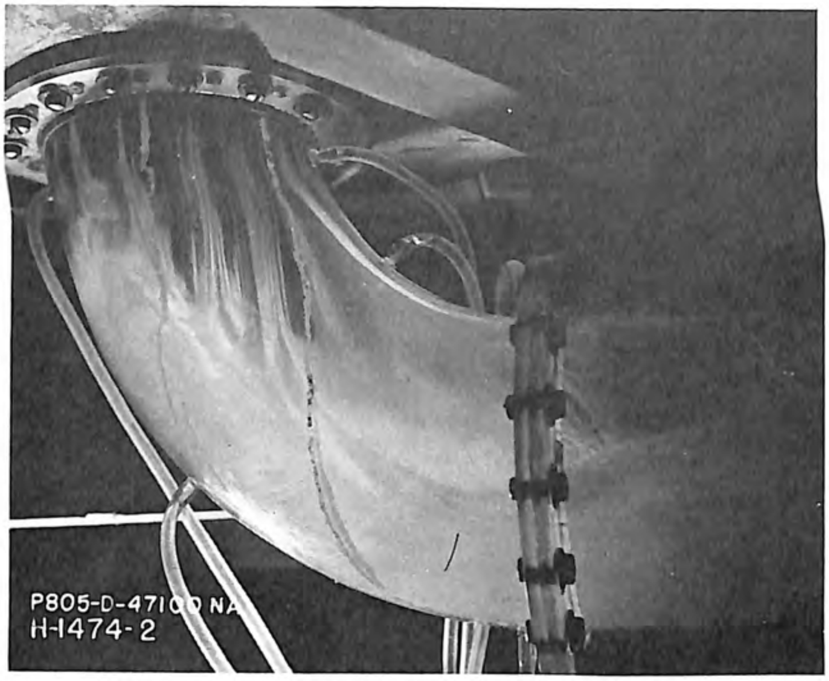


B. 3,600 cfs

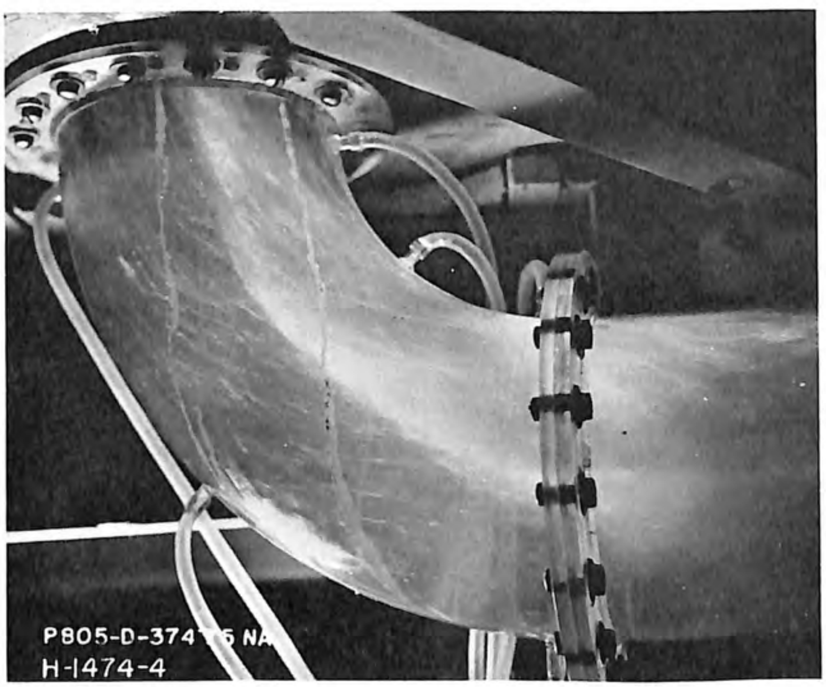
SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE PRELIMINARY INLET

1:21.91 Scale Model

Figure 10
Report Hyd-517



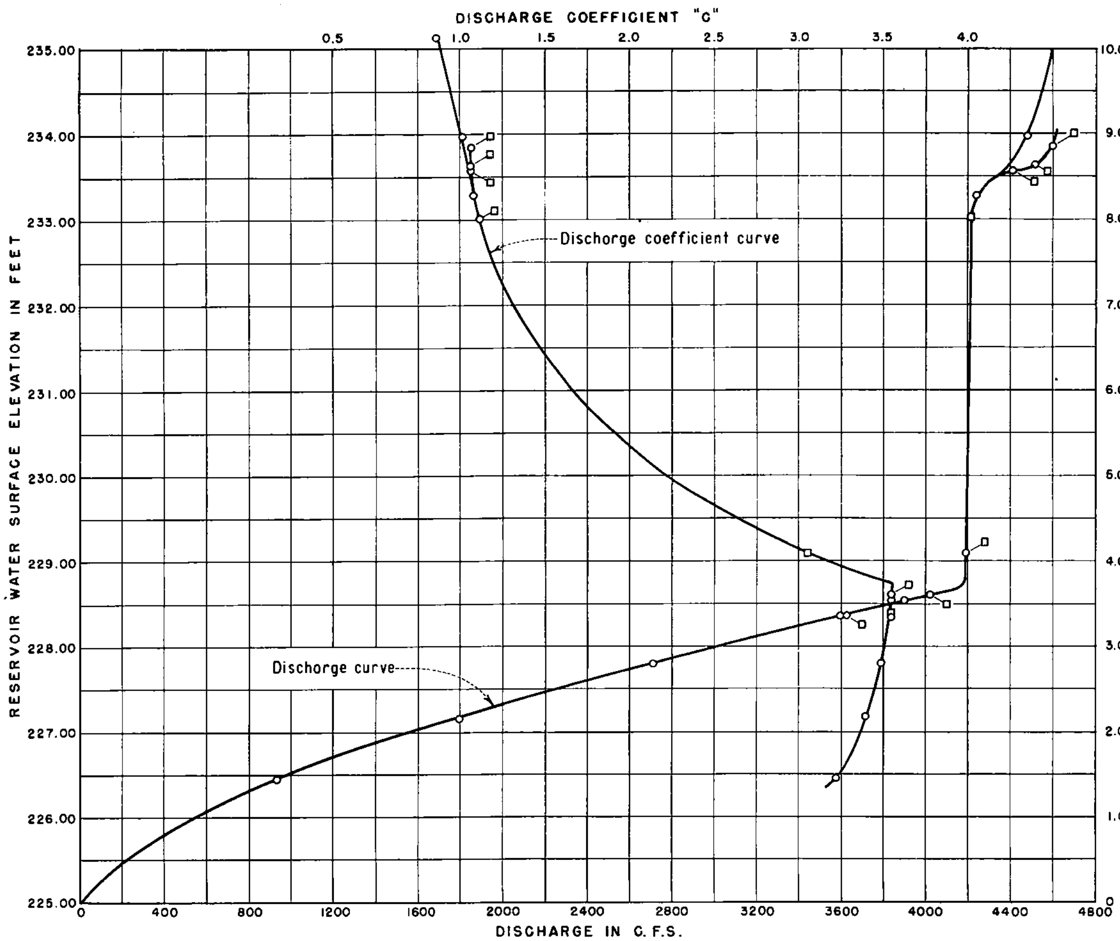
A. 1,800 cfs



B. 3,600 cfs

SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE PRELIMINARY VERTICAL BEND

1:21.91 Scale Model



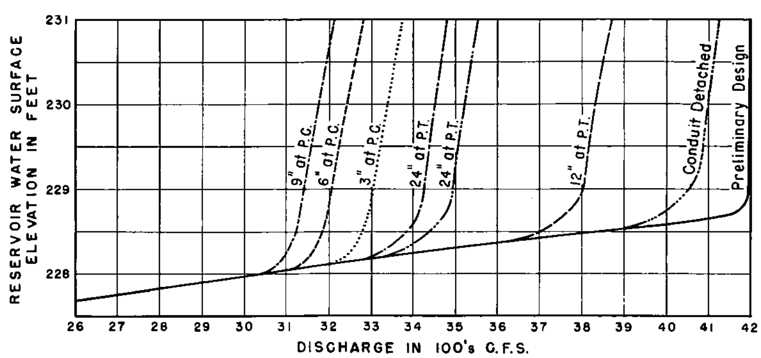
EXPLANATION

- Preliminary design with bend vented.
- Preliminary design with no venting.
- 3-inch deflector and vent at P.C. of bend.
- 6-inch deflector and vent at P.C. of bend.
- 9-inch deflector and vent at P.C. of bend.
- 12-inch deflector and vent at P.T. of bend.
- 24-inch deflector and vent at P.T. of bend.
- 24-inch deflector and vent at P.T. of bend. (Bend lowered 2 feet)
- Conduit detached at throat of inlet.

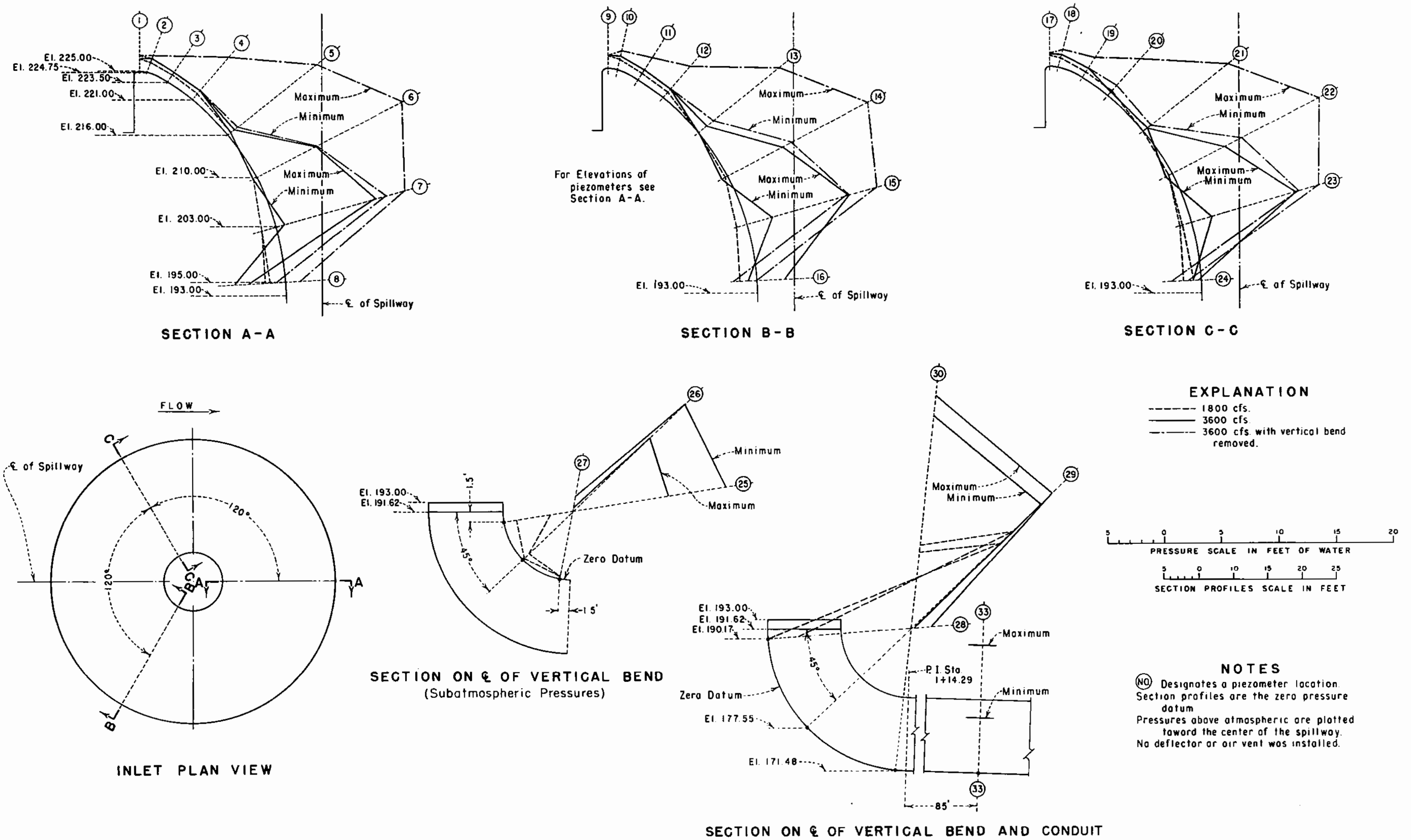
$$Q = CLH^{3/2}$$

Where:

Q = Discharge in c.f.s.
L = Crest Length = 165.50 feet.
C = Coefficient of Discharge
H = Head on crest in feet



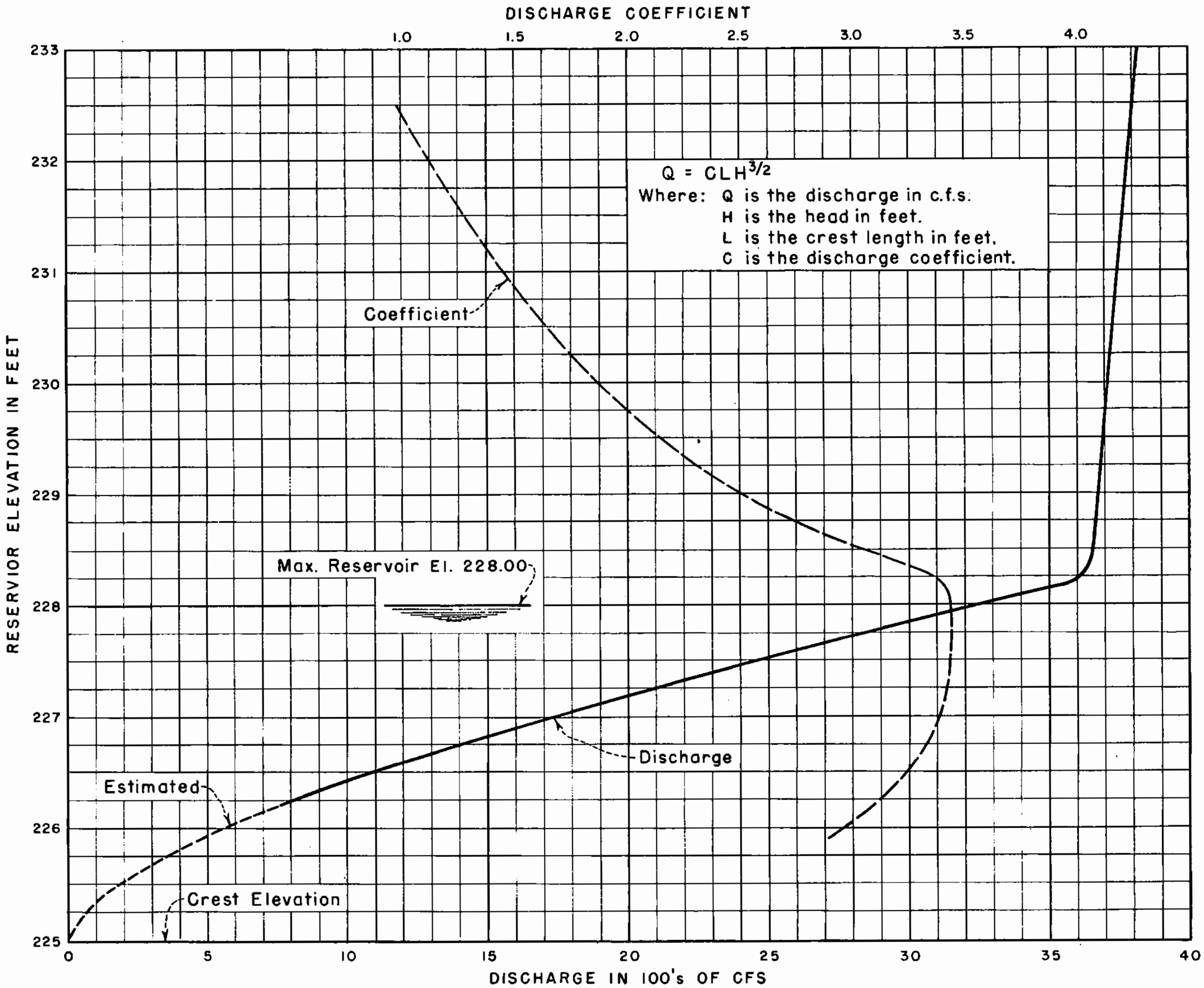
SAN LUIS FOREBAY DAM SPILLWAY
DISCHARGE AND COEFFICIENT CURVES
1:21.91 SCALE MODEL



SAN LUIS FOREBAY DAM SPILLWAY

PRESSURES IN THE PRELIMINARY INLET AND VERTICAL BEND

1:21.91 SCALE MODEL



SAN LUIS FOREBAY DAM SPILLWAY
DISCHARGE AND COEFFICIENT CURVES FOR THE RECOMMENDED DESIGN
1:24.52 SCALE MODEL

FIGURE 13
REPORT HYD-517

A. 3,250 cfs with wind-generated waves.

B. 3,250 cfs

C. 2,500 cfs

D. 1,500 cfs

E. 800 cfs

F. 3,600 cfs

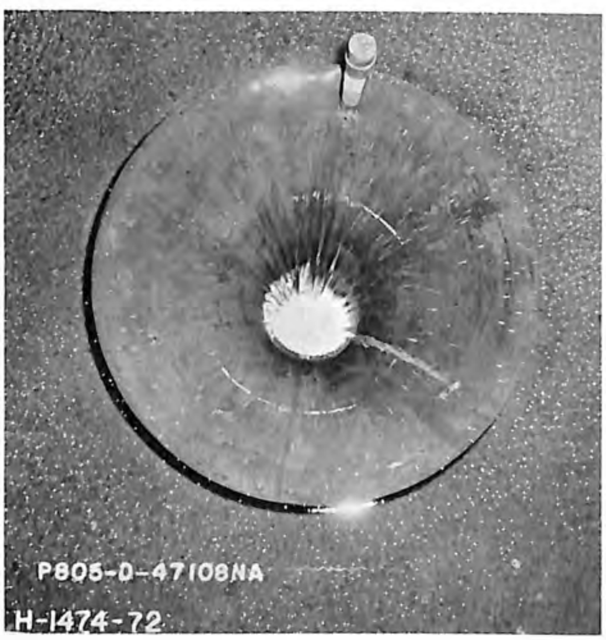
SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE RECOMMENDED INLET APPROACH AREA

1:24.52 Scale Model

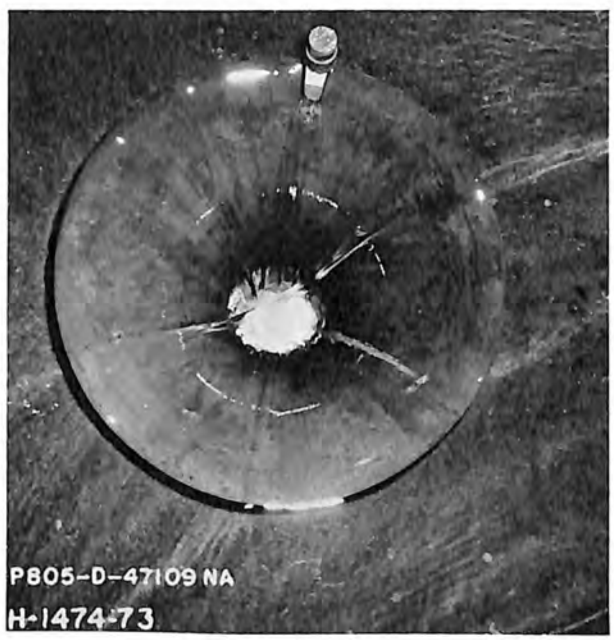
Figure 15
Report Hyd-517

A. 3,250 cfs

B. 3,250 cfs with waves.



C. 800 cfs



D. 800 cfs with waves.

SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE RECOMMENDED INLET

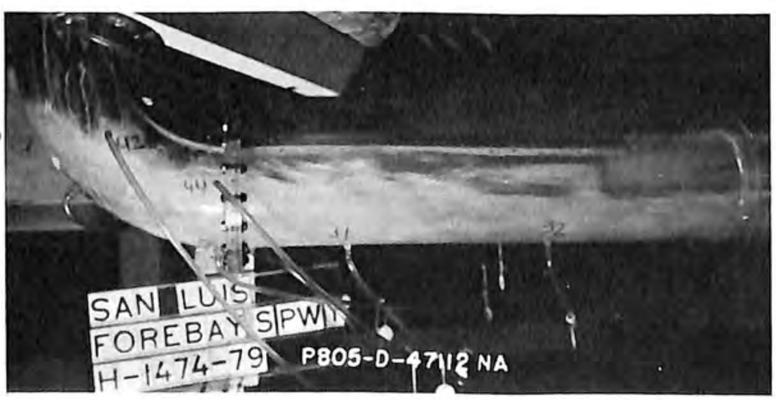
1:24.52 Scale Model

Figure 16
Report Hyd-517

A. 3,250 cfs

B. 3,250 cfs
with reservoir waves.

C. 1,500 cfs



D. 1,500 cfs
with reservoir waves.

SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE RECOMMENDED VERTICAL BEND

1:24.52 Scale Model

Figure 17
Report Hyd-517

A. 3,250 cfs

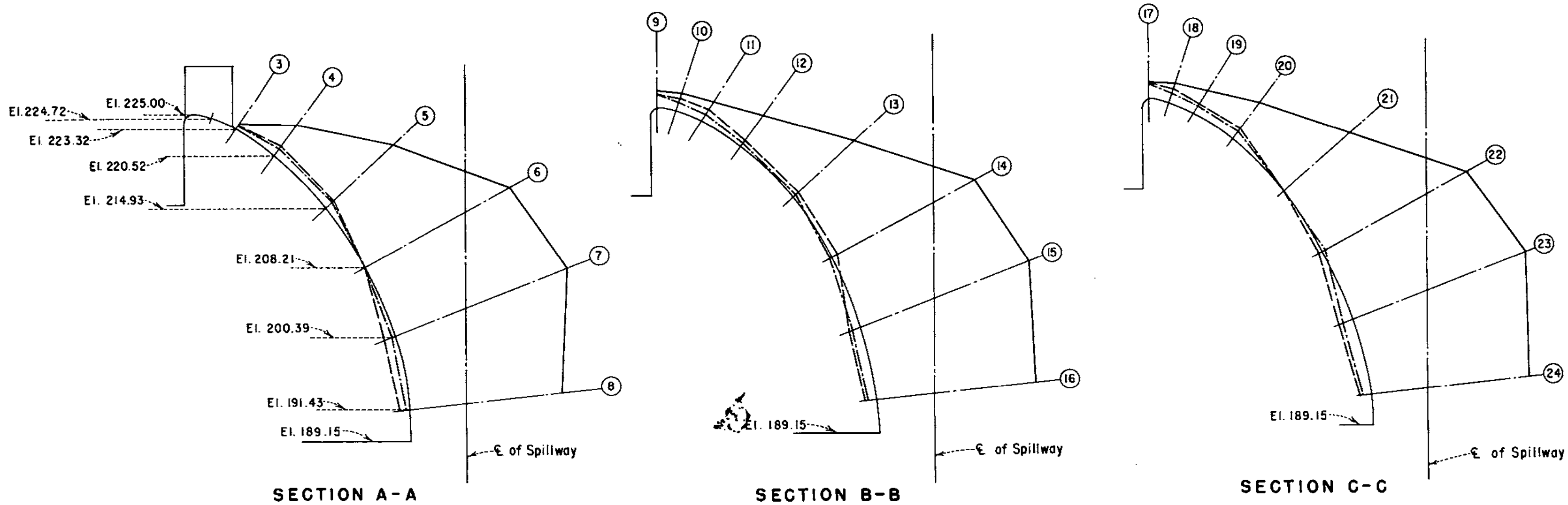
B. 3,250 cfs
with reservoir waves.

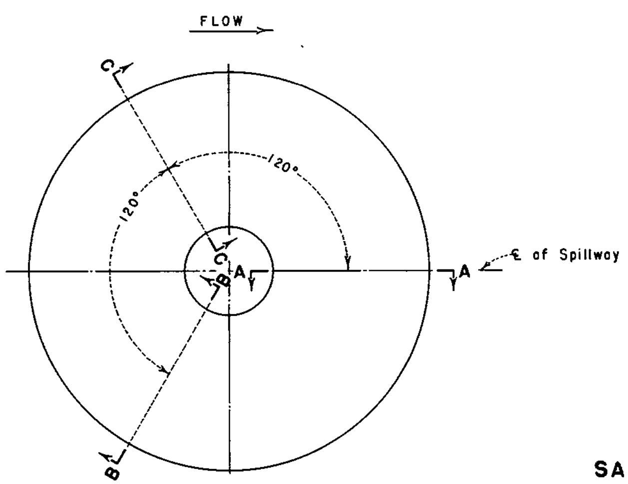
C. 1,500 cfs

D. 1,500 cfs
with reservoir waves.

SAN LUIS FOREBAY DAM SPILLWAY
FLOW IN THE RECOMMENDED CONDUIT

1:24.52 Scale Model





INLET PLAN VIEW

KEY DIAGRAM

5 0 5 10 15

SECTION PROFILES SCALE IN FEET
AND
PRESSURE SCALE IN FEET OF WATER

EXPLANATION

- 1500 c.f.s.
- 3250 c.f.s.
- 3600 c.f.s.

NOTES

(No) Designates a piezometer location.
Section profiles are the zero pressure datum.
Pressures above atmospheric are plotted normal to the section profile.
Piezometer elevations are identical in Sections A-A, B-B and C-C

SAN LUIS FOREBAY DAM SPILLWAY

PRESSURES IN THE RECOMMENDED INLET

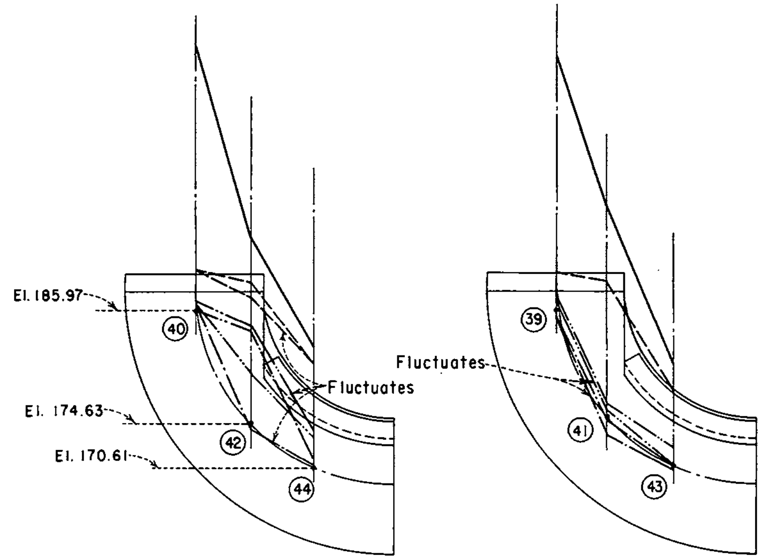
1:24.52 SCALE MODEL

FIGURE 18
REPORT HYD-517

PRESSURES AND FLOW DEPTH*

PIEZ. NO.	3600 c.f.s.		3250 c.f.s.		2500 c.f.s.		1500 c.f.s.	
	PRESS FT. H_2O	FLOW DEP. FT.	PRESS FT. H_2O	FLOW DEP. FT.	PRESS FT. H_2O	FLOW DEP. FT.	PRESS FT. H_2O	FLOW DEP. FT.
28	27.20	11.75	5.40 to 11.90	2.0	2.20 to 4.0	1.25	2.70 to 1.50	1.00
29	33.50	9.25	29.80	8.75	25.00 to 24.40	4.25	20.10 to 21.00	2.50
30	31.50	7.25	26.0	6.75	21.20	5.25	14.50	3.50
31	7.90	6.75	7.40	6.75	5.70	5.25	4.50	4.00
32	7.10	6.50	6.50	6.25	5.20	5.25	3.90	4.00
33	7.10	6.75	6.80	6.50	5.30	5.25	4.50	4.50
34	6.80	6.75	6.60	6.50	5.30	5.25	4.00	4.00

* Flow Depths measurements were estimated and are not accurate closer than to about 0.25 feet.



RIGHT SIDE PIEZOMETERS

LEFT SIDE PIEZOMETERS

VERTICAL BEND

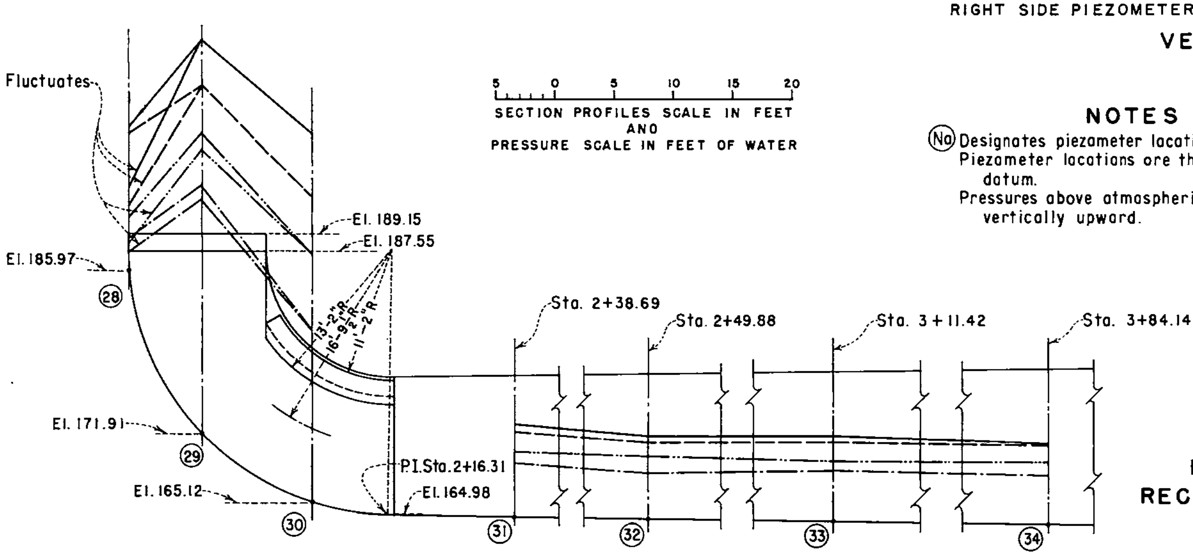
5 0 5 10 15 20
SECTION PROFILES SCALE IN FEET
AND
PRESSURE SCALE IN FEET OF WATER

NOTES

(No) Designates piezometer location.
Piezometer locations are the zero pressure datum.
Pressures above atmospheric are plotted vertically upward.

EXPLANATION

———— 3600 c.f.s.
— — — 3250 c.f.s.
—·—·— 2500 c.f.s.
—··—··— 1500 c.f.s.



VERTICAL BEND AND CONDUIT SECTION

SAN LUIS FOREBAY DAM SPILLWAY
PRESSURES AND FLOW DEPTHS IN THE RECOMMENDED VERTICAL BEND AND CONDUIT
1:24.52 SCALE MODEL

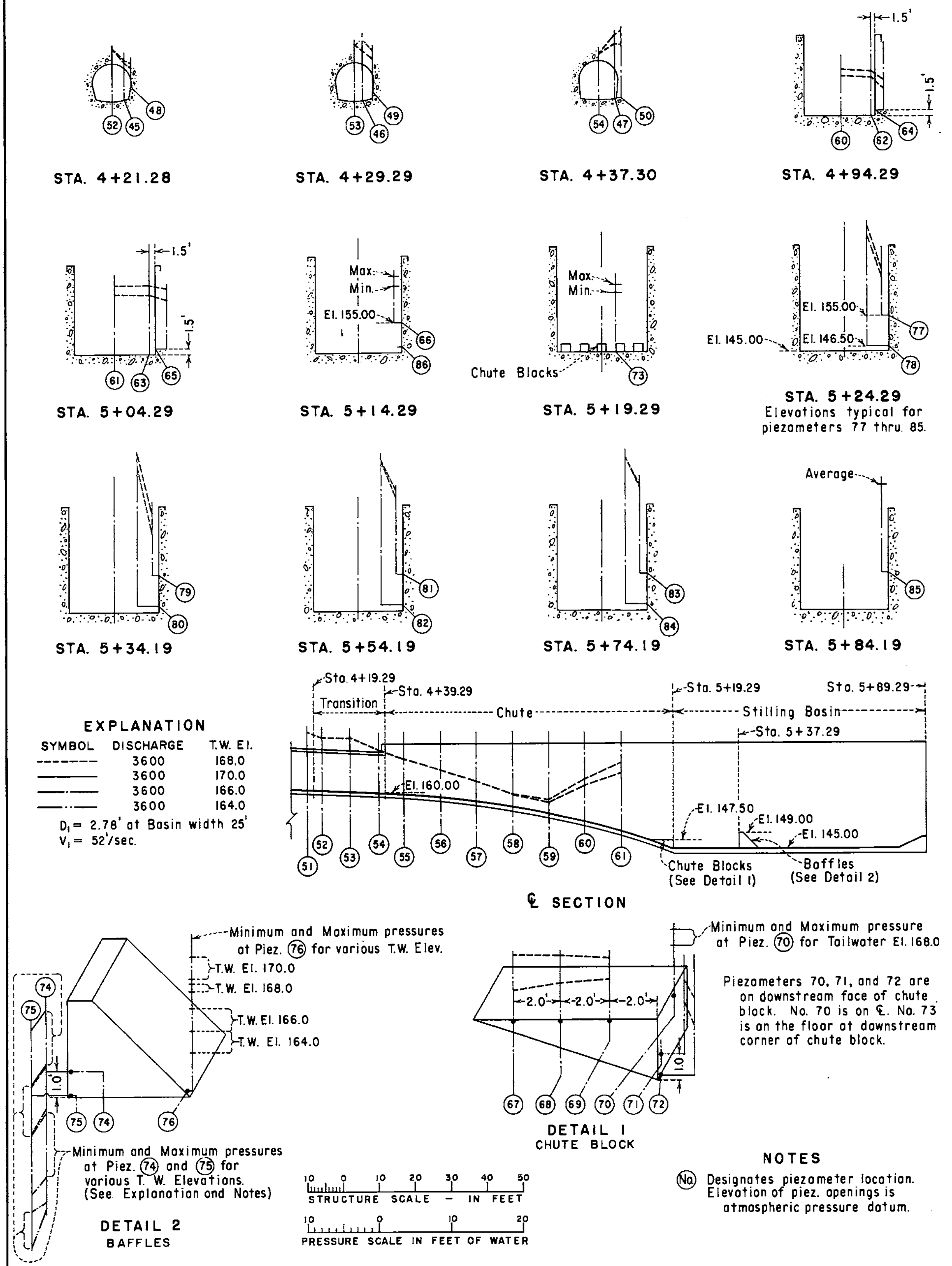
A. 3,600 cfs T.W. Elev. 168.00

B. Erosion after 2 hours of model operation at 3,600 cfs.

Note: V_1 = 63.7 fps and D_1 = 2.26 feet

SAN LUIS FOREBAY DAM SPILLWAY
FLOW AND EROSION IN THE PRELIMINARY BASIN

1:21.91 Scale Model



SAN LUIS FOREBAY DAM SPILLWAY
PRESSURES IN THE PRELIMINARY TRANSITION SECTION AND STILLING BASIN
1:21.91 SCALE MODEL

667

A. 3,600 cfs T.W. Elev. 170.00

B. 3,600 cfs T.W. Elev. 170.00

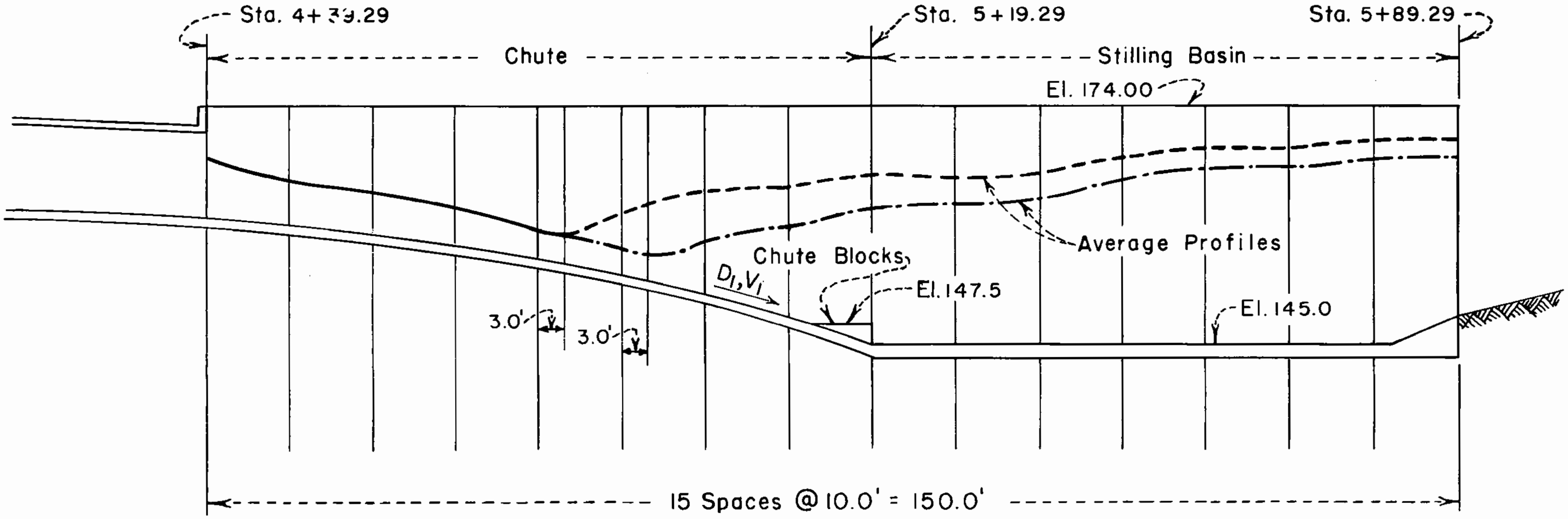
C. Before erosion test.

D. Erosion after 2 hours of model operation at 3,600 cfs.

Note: V_1 = 57.8 fps and D_1 = 2.5 feet

SAN LUIS FOREBAY DAM SPILLWAY
FLOW AND EROSION IN THE FIRST MODIFIED BASIN

1:21.91 Scale Model



10 0 10 20 30 40 50

SCALE OF FEET

EXPLANATION

SYMBOL	DISCHARGE	T. W. EL.
– – – – – –	3600	170.00
–·——·–	3600	168.00

D_1 = 2.78 feet, V_1 = 52 feet per second

Froude number = 5.5

SAN LUIS FOREBAY DAM SPILLWAY

WATER SURFACE PROFILES IN THE FIRST MODIFIED BASIN

1:21.91 SCALE MODEL

FIGURE 23
REPORT HYD-517

667

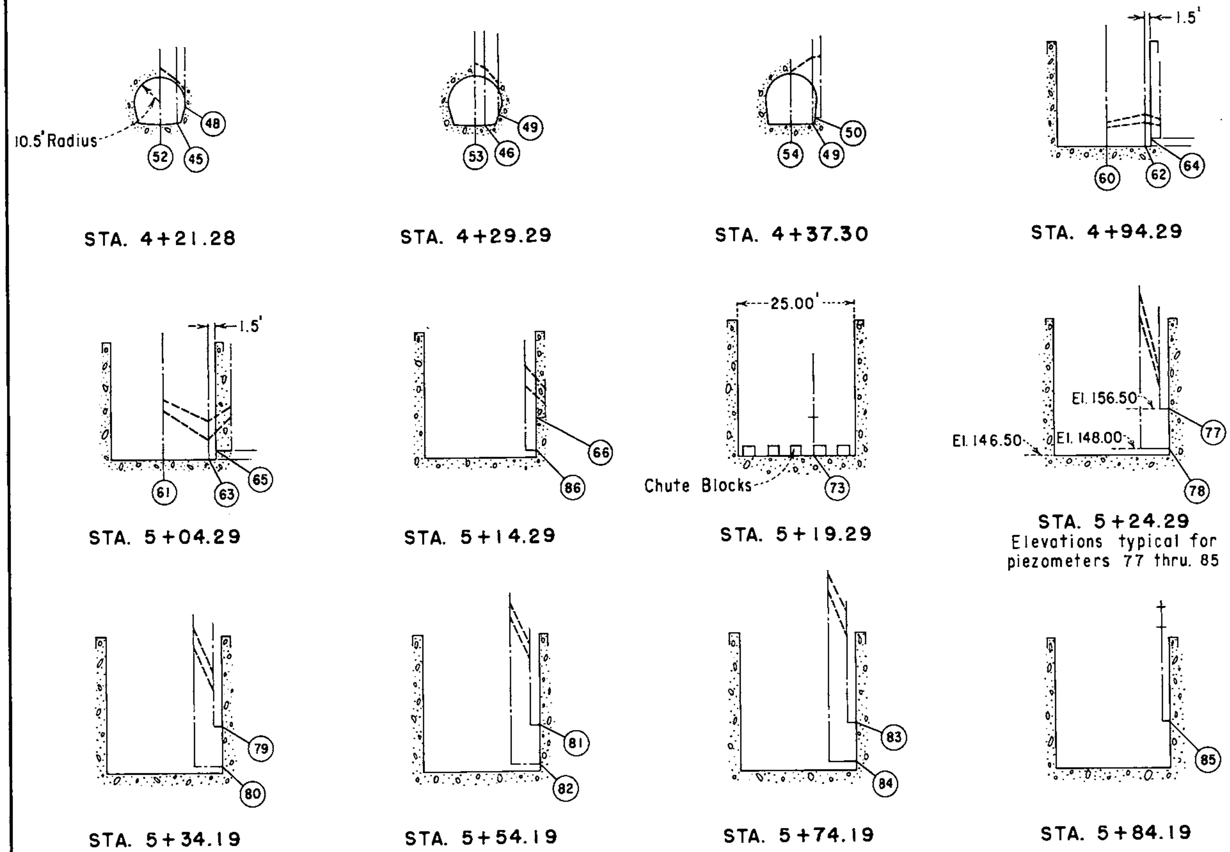
A. 3,600 cfs T.W. Elev. 170.00

B. Erosion after 2 hours of model operation at 3,600 cfs.

Note: V_1 = 63.7 fps and D_1 = 2.26 feet

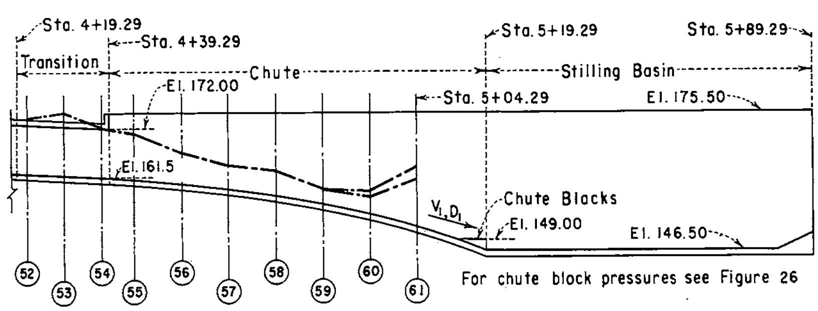
SAN LUIS FOREBAY DAM SPILLWAY
FLOW AND EROSION IN THE SECOND MODIFIED BASIN

1:21.91 Scale Model



* DYNAMIC PRESSURES IN FEET OF WATER					
PIEZOMETER NUMBER	AVERAGE MAXIMUM	AVERAGE MINIMUM	MEAN	MAXIMUM FLUCTUATION	⊗ TAILWATER ELEVATION FEET
61	22	2	12	44	172
86	18	7	12	40	172
66	10	1	5	22	172
85	16	13	14	2	172
61	13	0	7	35	170
86	15	3	9	33	170
66	6	−1	3	18	170
85	15	10	12	9	170
61	1	1	1	9	168
86	4	−2	1	20	168
66	—	—	—	—	168
85	11	7	9	11	168
61	1	1	1	0	166
86	−1	−6	−4	5	166
66	—	—	—	—	166
85	9	5	7	9	166

* Pressures obtained by transducers.
⊗ Tailwater elevation shown are for the modified basin.
Subtract 0.5 feet for the recommended bosin.



For chute block pressures see Figure 26

℄ SECTION

EXPLANATION

------ Water Manometer pressure gradients for 3600 c.f.s. at tailwater elevation 170.00 in the modified basin and for 3600 c.f.s. at tailwater elevation 169.50 in the recommended basin.

—·—·— Water Manometer pressure gradients in preliminary transition and chute for 3600 cfs. at tailwater elevation 3170.

10 0 10 20 30 40 50
STRUCTURE SCALE — IN FEET

NOTES

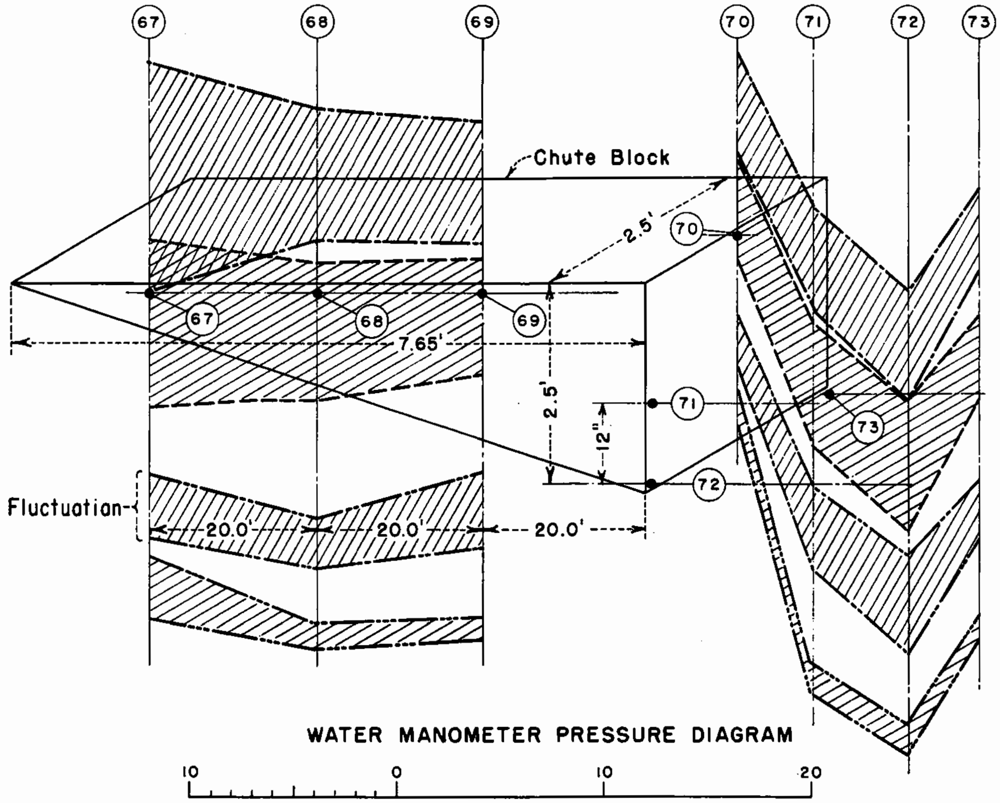
(No) Designates piezometer location.
Elevation of piezometer openings is atmospheric pressure datum.
Average entrance velocity, V_1 and depth D_1 equal 60 feet per second and 2.4 feet respectively.

10 0 10 20
WATER MANOMETER PRESSURE SCALE IN FEET OF WATER

SAN LUIS FOREBAY DAM SPILLWAY

PRESSURES IN PRELIMINARY TRANSISTION AND CHUTE, SECOND MODIFIED BASIN, AND RECOMMENDED BASIN

1:21.91 SCALE MODEL



WATER MANOMETER PRESSURE DIAGRAM

WATER MANOMETER PRESSURES IN FEET OF WATER

EXPLANATION

All flows = 3600 c.f.s.

- ———— Tailwater El. 172.00
- – – – – – Tailwater El. 170.00
- –·–·–·– Tailwater El. 168.00
- –··–··– Tailwater El. 166.00

NOTES

(NO.) Designates piezometer location. Elevation of piezometer openings is atmospheric pressure datum. (73) is on the basin floor. Entrance velocity at chute blocks V_1 and depth D_1 equal 60 feet per second and 2.4 feet respectively. See Figure 25 for other basin pressures.

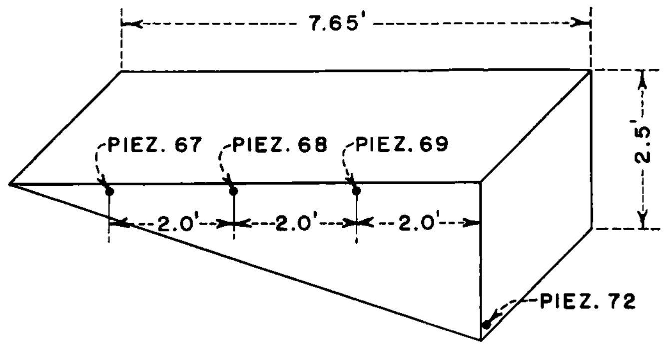
* DYNAMIC PRESSURES IN FEET OF WATER					
PIEZOMETER NUMBER	AVERAGE MAXIMUM	AVERAGE MINIMUM	MEAN	MAXIMUM FLUCTUATION	TAILWATER ELEVATION
67	29	-11	9	75	172
72	18	0	9	14	172
67	20	-15	3	88	170
72	11	- 4	4	66	170
67	- 4	-13	- 8	44	168
72	0	- 9	- 4	35	168
67	-11	-15	-13	10	166
72	- 9	-13	-11	5	166

* Pressures obtained by transducers.

SAN LUIS FOREBAY DAM SPILLWAY

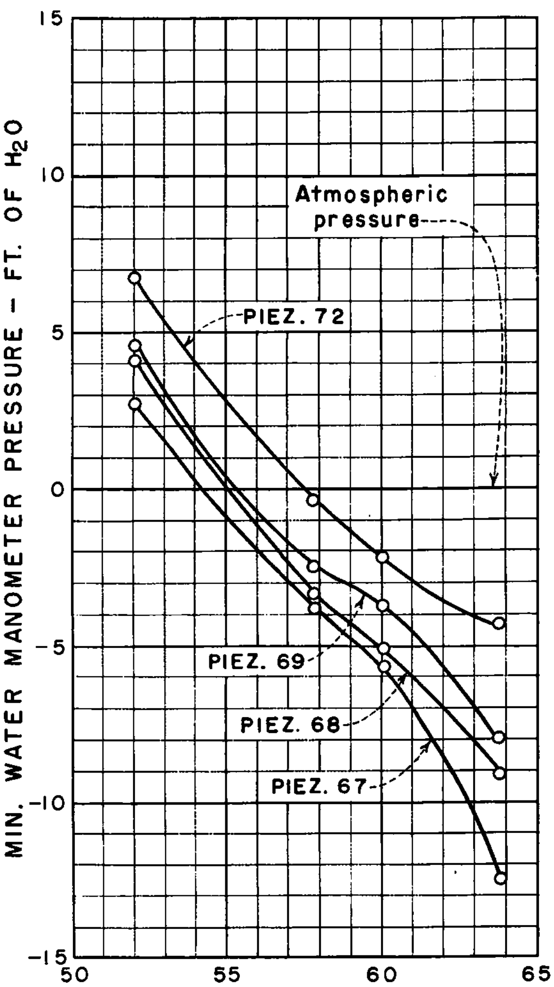
CHUTE BLOCK PRESSURES IN THE SECOND MODIFIED BASIN

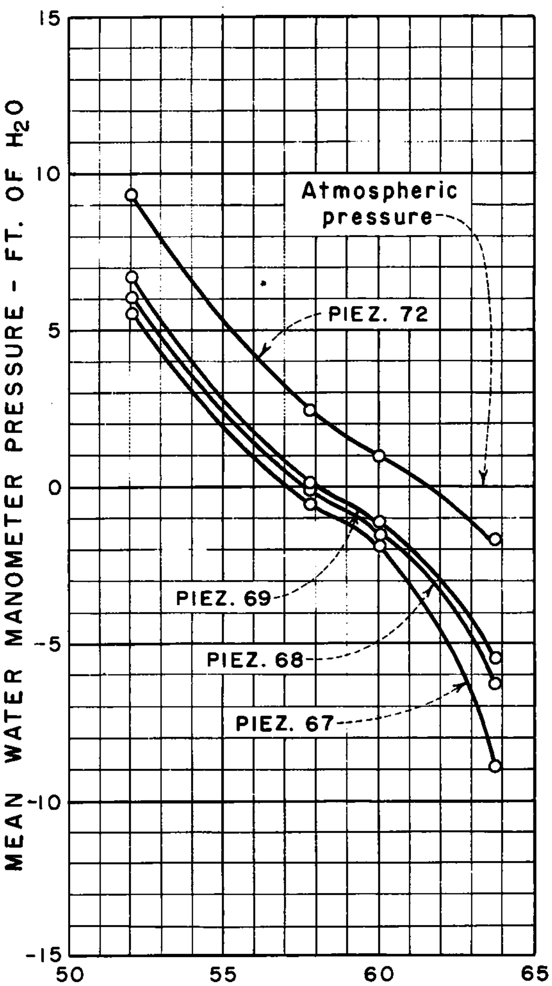
1:21.91 SCALE MODEL



Discharge Q = 3600 c.f.s.
Velocity V_1 computed at chute blocks for basin width of 25 feet.
Basin Apron at El. 146.50
Tailwater at El. 170.00

CHUTE BLOCK PIEZOMETER LOCATIONS





SAN LUIS FOREBAY DAM SPILLWAY
CHUTE BLOCK PRESSURES VS. ENTRANCE VELOCITY IN SECOND MODIFIED BASIN
1:21.91 SCALE MODEL

A. 3,250 cfs T.W. Elev. 169.5

B. 3,250 cfs T.W. Elev. 169.50

Note: V_1 = 63.7 fps and D_1 = 2.26 feet

C. 900 cfs T.W. Elev. 165.25

D. Erosion after 2 hours of model operation at 3,250 cfs.

SAN LUIS FOREBAY DAM SPILLWAY
FLOW AND EROSION IN THE RECOMMENDED BASIN

1:21.91 Scale Model

7-1750
(10-64)

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second

Multiply	By	To obtain
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 845-237

ABSTRACT

Model studies were conducted to develop the hydraulic design of the morning glory inlet and its approach, the vertical bend, the horizontal conduit, and the stilling basin. The diameter of the morning glory inlet and conduit was increased to accommodate the design flow at maximum reservoir elevation. A deflector, air vent, and guide vanes were installed in the vertical bend to direct the flow to the invert of the conduit and to reduce the oscillation of the flow through the conduit. The size of the stilling basin was increased and the end sill modified to eliminate the need for intermediate baffle piers.

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Report No. Hyd-517

Report No. Hyd-517
G. L. Beichley
HYDRAULIC MODEL STUDIES OF SAN LUIS FOREBAY DAM SPILLWAY
Laboratory Report, Bureau of Reclamation, Denver, 13 p, 28 fig, 1 tab, 3 ref, 1964

DESCRIPTORS--*Spillways/ spillway crests/discharge coefficients/ hydraulic conduits/bends/hydraulic models/piezometers/*stilling basins/guide vanes/hydraulic jumps/hydraulic similitude

IDENTIFIERS--*Morning glory inlets/subatmospheric pressures/ conduit deflectors/baffle blocks

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